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STANDARDIZED WINDSHIELD FABRICATION SPECIFICATION.(U)

NOV 77 R I BECK, L P KOEGEBOEHN, J H LAWRENCE F33615-75-C-3105

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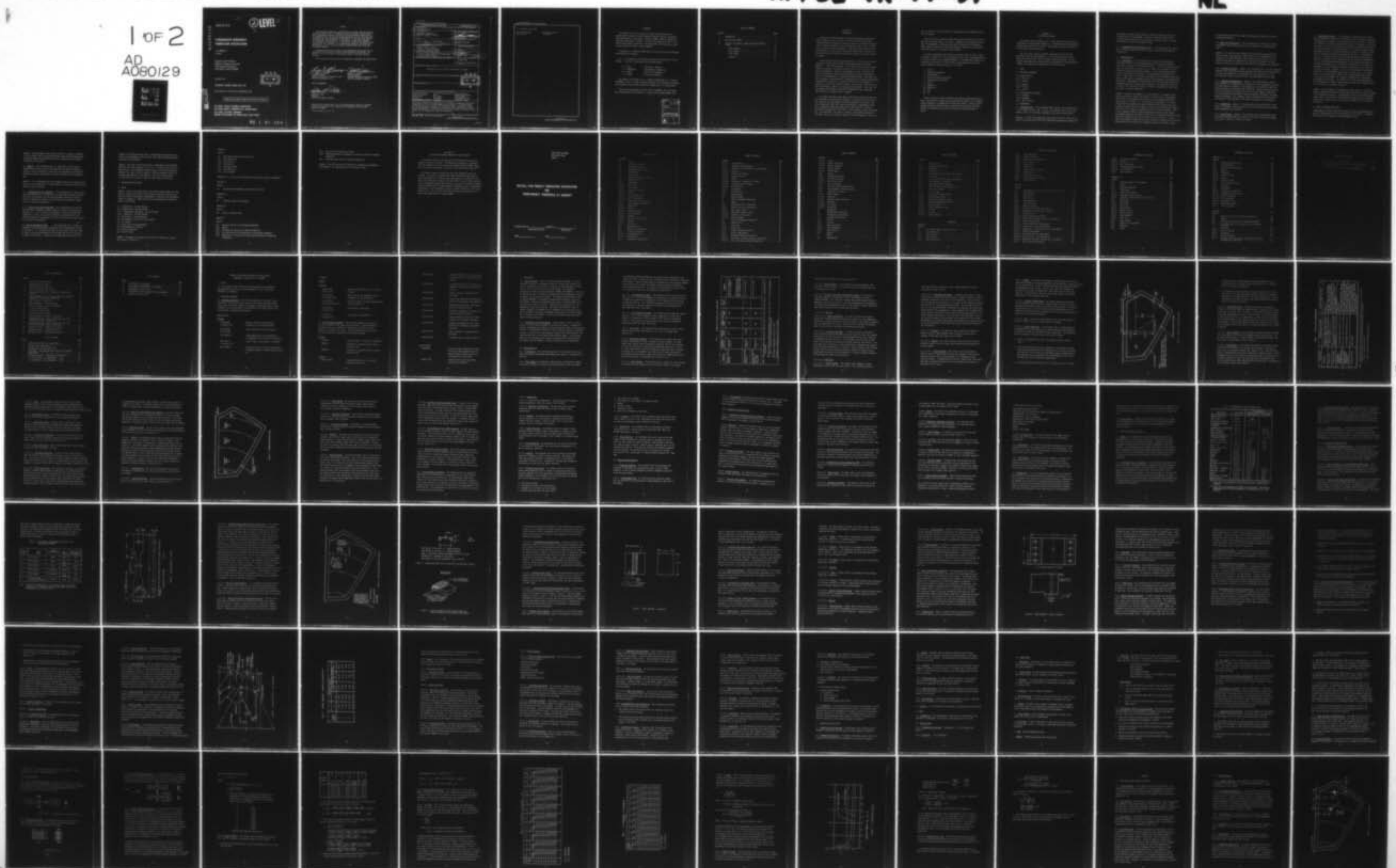

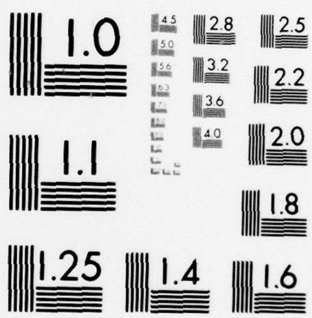
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AFFDL-TR-77-97

STANDARDIZED WINDSHIELD FABRICATION SPECIFICATION

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November 1977

TECHNICAL REPORT AFFDL-TR-77-97

Final Report For Period June 1976-October 1977

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AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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Environmental Testing	Laminated	Production tests

20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

The report documents the preparation of a windshield transparency fabrication specification for a high performance military aircraft. The specification formatting and textual content are briefly discussed. The report utilizes an example document to present the standardized text required for structural, impact, temperature, anti-ice/de-fog, P-static and optical performance requirements and the preproduction testing requirements.

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FOREWORD

This report is one of a series of reports that describes work accomplished by Douglas Aircraft Company, McDonnell Douglas Corporation, 3855 Lakewood Blvd., Long Beach, California 90846, under the Windshield Technology Demonstrator Program. This work was sponsored by the U.S. Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, under Contract F33615-75-C-3105, Project 22020201.

Lieutenant L. G. Moosman (AFFDL/FEW) was the Air Force Project Manager who monitored the program.

Mr. J. H. Lawrence, Jr. was Program Director for the Douglas Aircraft Company. Principal investigators and co-authors were:

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The authors are grateful to R. L. Peterson (AFFDL/FEA), D. L. Russell (ASD/ENFSS), and D. C. Chapin (Texstar Plastics) for periodically reviewing this document and providing constructive suggestions in a timely manner.

This work was submitted to the Air Force in November 1977 and covers work performed during the period of 1 January 1977 through October 1977.

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SECTION I
INTRODUCTION

The Douglas Aircraft Company's Windshield Technology Demonstrator (WTD) Program, as part of the Air Force Flight Dynamics Laboratory Improved Windshield Protection Program, developed a windshield design for a multi-layered transparency that includes anti-static, anti-ice/defog and bird impact protection features. Additional design features that were necessary for the specific windshield examples were included that are program system oriented and may not be germane to any other program or system.

The WTD Program required the preparation of a Critical Item Product Fabrication Specification (CIPFS) in accordance with MIL-STD-490, Appendix X. The CIPFS presented in this report reflects the WTD design, materials research, testing and evaluation of the B-1 aircraft initial design requirements. Normally a development or Part I specification would be prepared to contain the performance and testing requirements prior to the preparation of a fabricarion specification. The CIPFS, for the WTD program, encompasses both preproduction and production performance requirements and testing. The detailed fabrication is presented on a drawing to a level that allows a supplier some latitude in using his own design techniques, materials and fabrication processes. Thus, more than one supplier may conform to the CIPFS requirements using a separate detail drawing or drawings for his product.

This report describes the standard specification format used and presents excerpts from MIL-STD-490, Appendix X, that explain the rationale for including the requirements and testing defined in the CIPFS. The basic structure of the CIPFS could be considered a standardized format for a windshield transparency fabrication specification. The basic functional requirements of anti-static, anti-ice/defog, impact resistance, etc., are described. The explicit numerical requirements presented in the CIPFS, apply to the specific design, mission requirements, materials,

etc., of the B-1 aircraft windshield transparency design developed during the WTD program.

Section II of this report presents the sectional format of the CIPFS to the third paragraph level, i.e., 4.2.4. Comments are included on various specific paragraphs or sections which need clarification or alteration. These comments compare the format and paragraph content to the "required" format and content as specified in MIL-STD-490.

The total windshield specification, from front cover to back, is then presented in Section III. The requirements, tests, etc., are separated into six sections which are considered mandatory in a standardized format, with appendices as necessary to clarify tests or requirements which do not exist elsewhere. The basic format is as follows:

1. Scope
2. Applicable documents
3. Requirements
4. Quality assurance provisions
5. Preparation for delivery
6. Notes
10. Appendix I
20. Appendix II
30. etc.
40. etc.

Other air vehicle system windshield transparency performance requirements, new materials, technology and manufacturing methods will eventually produce changes to a standard CIPFS format and content. However, these changes should not effect the basic function of disclosing a detailed design for production and testing by prime and alternate sources of supply.

SECTION II
SPECIFICATION FORMAT

The format, section content, etc., of the CIPFS, follows the primary requirements of MIL-STD-490, Appendix X. MIL-S-83490 provided additional direction and definitions of terms. MIL-STD-483 was used as the source for the CIPFS cover page format.

The first level sections and their sub-level sections are fully explained in MIL-STD-490, Appendix X. The following format outline down to the third level lists the primary sections required. Section content requirements have been extracted from Appendix X where additional comments are required for comparison to the CIPFS content.

1. SCOPE

2. APPLICABLE DOCUMENTS

2.1 Specifications

2.1.1 Military

2.1.2 Federal

2.2 Standards

2.2.1 Military

2.2.2 Federal

2.3 Non-Government Documents

2.3.1 Drawings

2.3.2 Standards

2.3.3 Specifications

3. REQUIREMENTS

3.1 <u>Item Definition</u>. "This paragraph shall provide a brief description of the subject critical item. It shall also identify the: a) major components, and b) the individual components that must be manufactured".

Comment: To allow the transparency manufacture sufficient flexibility to match the selected design with their manufacturing expertise, methods and

proprietary processes design options or materials substitutions might be described in this paragraph. Individual components should not be included under item definition when they are defined by detail drawings which would be a part of the specification.

3.1.1 Government Furnished Property List. "This paragraph lists government furnished property, which the critical item shall be designed to incorporate."

3.2 Characteristics

3.2.1 Performance. "This paragraph shall include those performance requirements which are to be demonstrated by the quality conformance inspections in Section 4 of the specification. It may also include requirements for performance, reliability, etc., when such requirements are not completely controlled by detail drawings. In no instance should contradicting requirements be specified. All requirements included herein shall, in most cases, be limited to performance at environmental conditions normal to the place of acceptance and shall not attempt to simulate service environment. Requirements included herein shall be specified in physically measurable quantitative terms with tolerances. Such performance shall be in terms of the item itself without reference to equipments of facilities with which it must be compatible."

Comment: The above requirements, for the content of a windshield transparency performance section, may result in the writing of a performance section that is too general and would not include adequate performance requirements for Section 3.4. The windshield transparency is a critical safety item and therefore the supplier should be fully aware of all performance and tests that he may have to initiate including obtaining special facilities if the quality of production parts is to be controlled. Particularly, emphasis should include sufficient description of the thermal requirements generated by climatic conditions. The description must include those test conditions that are to be met as part of Section 3.4 testing. Those transparencies requiring electrical conductive coatings for anti-icing/defogging per MIL-T-5842 must be completely defined and tested in terms

of power density, electrical systems and temperature uniformity described by standard equations.

3.3 Design and Construction. "This paragraph shall include any essential requirements that are not controlled by the drawings or referenced documents".

Comment: This section is well defined in MIL-STD-490 and subdivided into three sections. One additional subdivision 3.3.4, is recommended to be included in any CIPFS developed. The purpose of subdivision 3.3.4 is to describe those material characteristics for which the supplier must periodically certify the uniformity of his materials, workmanship and processes.

3.3.1 Production Drawings. Comment: This paragraph shall list the production drawings, detail drawings and other documents that define the finished product including requirements for interchangeability or replaceability of the part relative to the aircraft to fulfill the requirements of MIL-I-8500.

3.3.2 Standards of Manufacture. Comment: This paragraph shall specify those processes and standards that are peculiar to the transparency supplier, but, when necessary commodities and standards are not specified, they shall then be selected in accordance with MIL-STD-143. Special attention must be given to the selection of materials relative to environmental conditions. For those dimensioned tolerances, shape configuration tolerances, finishes, weight requirements, hole alignment, and part identification not specified on drawings or other documents, they shall be included in this paragraph.

3.3.3 Workmanship. Comment: This paragraph shall provide specific workmanship requirements that may be peculiar to the product and or the manufacturers workmanship and processes.

3.3.4 Certification. Comment: This paragraph shall specify those items for which the manufacturer must certify in writing to the procuring agency those specific items for which he must test.

3.4 Preproduction Sample. "This paragraph, if provided, shall specify that a preproduction sample(s) shall be tested prior to regular production to demonstrate the adequacy and suitability of the contractor's processes and procedures in achieving the performance that is inherent in the design. Although in a function specification, the purpose of preproduction tests is to provide a basis for design approval, in a fabrication specification preproduction tests, like periodic production tests are intended to show that the techniques employed do not degrade the design. Preproduction tests in a fabrication specification are particularly necessary when a contract is awarded to a new source that has not previously produced the item. Selected performance requirements in the service environment may be added to Paragraph 3.2 of a fabrication specification to provide requirements upon which preproduction tests in Section 4 of the specification are to be based. However, since all such performance requirements should be in the development specification for the item, it will reduce the bulk of the fabrication specification if performance requirements in the service environment are invoked by referencing the associated development specification. In addition, the titles and requirements of this paragraph may be made to cover samples for periodic production tests if such tests are considered necessary."

Comment: The requirement for preproduction tests noted is a procuring agency responsibility that may be exercised at any time by specific request in the procurement contract. The applicable section in the CIPFS should always remain in the body of the specification and enables the immediate application of these sections in the event of product loss of quality or reliability.

4. QUALITY ASSURANCE PROVISIONS

"Requirements for formal tests verifications of the item performance and physical characteristics shall be specified in this section. In general, this section shall conform to the requirements of 4.4."

Comment: The requirement should clearly specify, as noted in Paragraph 3.4, only those items for verification that assure that the manufacturer is meeting drawing requirements and that his processes do not degrade the quality of the parts.

4.1 General. "This paragraph shall, as applicable, provide general information pertinent to tests and inspection not covered elsewhere in Section 4, such as location or conditions for preproduction and periodic production testing, requirements for special testing of item components, etc.".

Comment: It is recommended that this paragraph specify the frequency that parts are to be tested and if a sampling basis is authorized, then the plan should be clearly defined.

4.1.1 Responsibility for Inspection. "This paragraph shall usually state that the responsibility for performing all specified tests/verifications, rests with the supplier, and that the government reserves the right to witness or separately perform all tests specified or otherwise inspect any or all tests and inspections."

4.1.2 Special Tests and Examinations. "This paragraph shall cover the testing routine, sequence of tests, number of items to be tested, data required, etc., for all testing requirements for other than acceptance inspection. It shall also include, preferably in tabular form a correlation between each requirement, its test, and the type of unit on which the test shall be performed."

4.2 Quality Conformance Inspec[illegible]. "This paragraph shall include, or reference, test and examination procedures for all requirements covered in Section 3. All characteristics shall be classified as critical, major or minor, and other requirements of MIL-STD-490, Section 4.4.2 shall be included or referenced. In addition, this paragraph shall specify the

method of confirming that the item, as fabricated and assembled, complies with requirements of the critical item product fabrication specification and the drawings."

Comment: The CIPFS follows the Section 4 requirements of MIL-STD-490 except for the table referred to in 4.1.2. The type of test unit has been omitted. Test equipment should be added if the procuring agency requires this type of initial control. The test equipment could also be added upon approval of the supplier's test plan and procedures. The classification "critical, major or minor" have not been used.

5. PREPARATION FOR DELIVERY

6. NOTES

Comment: Section 6 has been used in the CIPFS to define terms, describe analysis methods that are not a direct part of the specification, and amplify or explain performance requirements of Section 3 and conformance control in Section 4. These sections are not contractually binding as noted in MIL-STD-490.

6.1 Intended Use - per MIL-STD-490
6.2 Ordering Data - per MIL-STD-490
6.2.1 Preproduction Specimens - per MIL-STD-490
6.2.2 Production - per MIL-STD-490
6.3 Definitions - per MIL-STD-490
6.4 Environmental Test Facility Description
6.5 Hail Impact
6.6 Static Drain Strap Requirement
6.7 Electromagnetic Isolation
6.8 Distortion Analysis
6.9 Core Ply Tests

Comment: Paragraphs 6.4 through 6.9 provide clarification of requirements noted in Section III.

Appendix I

Section

10. Bird Impact Qualification Test Plan

10.1 Test Objectives

10.2 Test Facility

10.3 Test Article

10.4 Test Description

10.5 Test Conditions

10.6 Test Procedure

Appendices II, III and IV have identical second level subjects as Appendix I.

Appendix II

Section

20. Accelerated Environmental Qualification Test Plan

Appendix III

Section

30. Interlayer Shear Test Procedure

Appendix IV

Section

40. Optical Distortion Test

Appendix V

Section

50. Selection and Use of the Referee Windshield

50.1 General

50.2 Procedure for Selection of Referee Windshield

50.3 Test Conditions for the Selection of the Referee Windshield

50.4 Procedure for Visual Optical Distortion Evaluation of Production Windshields.

50.5 Visual Optical Distortion Criteria

50.6 Magnitude Estimation Procedure for Contractor Review of Marginal Windshield

50.7 Procuring Agency Review of Marginal Windshield.

Comment: The CIPFS has used the above basic formatting of appendices. Each appendix is a contractual part of the basic CIPFS.

SECTION III
CRITICAL ITEM PRODUCT FABRICATION SPECIFICATION

This section contains the complete CIPFS developed during the WTD program for the B-1 aircraft. The document was prepared in accordance with MIL-STD-483 for the cover page, MIL-S-83490 and MIL-STD-490, Appendix X for format and content of sections as was described in Section II.

The reader is again reminded that the CIPFS presented serves two purposes. To present a standardized product fabrication specification that incorporates all currently known requirements for a windshield system to the transparency industry and to be used as a preliminary guide for future transparency systems specification. The actual windshield selected to be the example for this specification incorporates many of the harshest requirements, and the greatest variety of systems, electrical, structural, optical, etc., into a single system thus allowing the dissemination of several new ideas within a single document.

SPECIFICATION NUMBER
CODE IDENT XXXXX
(DATE)

CRITICAL ITEM PRODUCT FABRICATION SPECIFICATION
FOR
TRANSPARENCY, WINDSHIELD, B-1 AIRCRAFT

AUTHENTICATED BY ______________ APPROVED BY ____________________

(Procuring Activity) (Contractor)

DATE__________________ DATE__________________

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CRITICAL ITEM PRODUCT FABRICATION SPECIFICATION
TRANSPARENCY, WINDSHIELD, B-1 AIRCRAFT

1. SCOPE

1.1 This specification establishes the requirements for manufacture and acceptance of the B-1 aircraft windshield critical item either Z5943224-1 or Z5943245-1.

2. APPLICABLE DOCUMENTS

2.1 Government Documents. The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

SPECIFICATIONS

Military

MIL-B-5087B 31 August 1970	Bonding, Electrical and Lightning Protection, for Aerospace Systems
MIL-G-25667A 29 July 1958	Glass, Monolithic, Aircraft Glazing
MIL-I-8500C(1)	Interchangeability and Replaceability of Component Parts for Aircraft & Missiles
MIL-P-83310 27 January 1971	Plastic Sheet, Polycarbonate, Transparent
MIL-T-5842(1)	Transparent Areas, Anti-Icing, Defrosting & Defogging Systems - General Specifications for

STANDARDS

Federal

Military

MIL-STD-1300 5 March 1971	Identification Marking of U.S. Military Property
MIL-STD-143B 12 November 1969	Specifications and Standards, Order of Precedence for the Selection of
MIL-STD-704A 7 May 1973 (Notice 4)	Electrical Power, Aircraft Characteristics and Utilization of
MIL-STD-810C 10 March 1975	Environmental Test Methods
MIL-STD-831 28 August 1963	Test Reports, Preparation of

2.2 Non-Government Documents. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on the data of invitation to bid or request for proposal shall apply. These documents shall be in effect only when specifically approved by the procuring agency.

DRAWINGS

Z5943242	Harness Assembly - Electrical, Windshield
Z5943224	Windshield - Laminated Glass, Cockpit Enclosure (DAC)
Z5943245	Windshield - Laminated Plastic, Cockpit Enclosure (DAC)

STANDARDS

ASTM-STD-D638	Standard Method of Test for Tensile Properties of Plastics

ASTM-STD-D881	Standard Method of Test for Deviation of Line of Sight Through Transparent Plastics
ASTM-STD-D1003	Standard Method of Test for Haze and Luminous Transmittance of Transparent Plastics
ASTM-STD-F428	Scratch Standard - Aerospace Glass Enclosures
ASTM-STD-F484	Stress Craze Resistance of Aerospace Plastic Transparencies, Test Method for
ASTM-STD-F319	Window Heating Element - Polariscope Method for Detecting Flaws
ASTM-STD-F330	Aerospace Transparency Enclosure Bird Impact Verification Testing
ASTM-STD-F521	Standard Method of Testing for Bond Integrity of Transparent Laminates
ASTM-STD-F320	Standard Test Method for Hail Impact Resistance of Aerospace Transparent Enclosures
ASTM-STD-F548	Scratch Standard - Aerospace Plastic Enclosures
ASTM-STD-D1925	Yellowness Index of Plastic, Test For

SPECIFICATIONS

L409C2004B	Electrical Power Characteristics and Utilization Requirements for B-1 Air Vehicle, General Specification for (North American Corporation)
(Number TBD)	Controller-Anti-ice, Three Phase, Three Sector Windshield.

3. REQUIREMENTS

3.1 Item Definition. The B-1 aircraft windshield assembly is a major component composed of transparency materials, formed and laminated into the B-1 windshield configuration, including the edge attachment, precipitation static provisions, and anti-icing system. Two different concepts are defined on Douglas Drawings Z5943245 and Z5943224. One of the configurations shall be chosen for production by the manufacturer, subject to approval by the procuring agency. The windshield configuration shown on Drawing Z5943245 is composed of polycarbonate structural plies, per MIL-P-83310, chemically strengthened outer glass, per MIL-G-25667, and an internal spall shield of acrylic. These plies are laminated with high temperature interlayer materials. The second configuration, shown on Drawing Z5943224, is composed of fully tempered glass structural plies, per MIL-G-25667, chemically strengthened glass outer ply, per MIL-G-25667, and an internal spall shield. The plies are laminated with high temperature interlayer materials.

3.1.1 Government Furnished Property. Certain specific items of tooling and test fixtures may be provided by the procuring agency. Included for tooling requirements are forming, drilling, holding fixtures, and associated tooling. A representative section of the air vehicle, that may be modified as noted in Section 20 for environmental (thermal and pressurization) life cycle testing, shall be provided by the procuring agency. The procuring agency, at its discretion, will select the testing facilities where the bird impact and environmental life-cycle testing will be accomplished.

3.2 Characteristics.

3.2.1 Performance. The windshield described in this specification shall meet the following performance requirements when tested in accordance with Section 4.

3.2.1.1 Bird Impact. The windshield, when mated to an appropriate support structure in a manner to simulate in-flight conditions, shall be capable

of withstanding without penetration or causing mission degradation, the impact of a four (4) pound bird at a minimum velocity of Mach 0.85 (565 knots) at sea level. The bird impact angle of incidence shall be the angle between the aircraft line of flight at 0^{o} angle of attack and the transparency in the installed position. The impact of the bird shall not cause injury to or physically impair air crew functional capabilities.

3.2.1.1.1 Low Temperature Impact. The windshield shall meet the requirements of 3.2.1.1 with the temperature on the exterior transparency surface of $-60^{o}F$ and an ambient air temperature of $75^{o}F$ adjacent to the interior transparency surface. This condition represents the aircraft flying for long durations at subsonic speeds at altitudes and then descending to below 8000 feet (AGL) (bird zone).

3.2.1.1.2 High Temperature Impact. The windshield shall meet the requirements of 3.2.1.1 with an exterior surface temperature of $230^{o}F$ and an ambient air temperature of $75^{o}F$ adjacent to the interior transparency surface. This condition represents the aircraft flying at supersonic speeds below 8000 feet (AGL) (bird zone).

3.2.1.2 Hail Impact. The windshield shall withstand hail impact without material failure, for stone sizes up to 0.8 inch in diameter (see Section 6.5).

3.2.1.3 Structural Integrity. The windshield shall sustain the static pressure requirements of Table I without structural damage. The windshield shall sustain the accelerated environmental test of two lifetimes of the cyclic pressure and associated temperatures specified in Section 20. One lifetime shall consist of 1000 cycles where one cycle is defined in Section 20. The windshield shall meet the bird impact and optical requirements specified herein after two lifetimes of temperature and pressure cycling testing in accordance with Section 4.1.2.3.

3.2.1.3.1 Proof Pressure. The windshield shall sustain 14.1 psig internal air pressure at room temperature for a period of fifteen (15) minutes

TABLE 1. WINDSHIELD PRESSURE TEST REQUIREMENTS

CONDITION	COMPONENT/ CONDITION	PRESSURE (PSIG)	SURFACE TEMP (°F)		NO. OF CYCLES	COMMENTS
			OUTER	INNER		
Maximum Internal Pressure	Windshield Ambient	21.2	3	3	1	Hold 2/3 maximum pressure for 5 minutes. Hold maximum pressure for 30 seconds at maxi-temp. (absolute value).
Maximum Crushing Pressures	Windshield Ambient	-9.3 2	3	3	1	Hold for 30 seconds
Maximum Internal Pressure at Max. Temp. (Required)	Windshield Hot	15.9	264	4 1		Hold for 30 seconds

NOTES: 1 Inside surface temperature resulting from 75 ± 5°F cabin air and h_i = 2.00 BTU/HR FT^2 °F (estimated).

2 With Centerline Crushing Distribution, P fwd = 18.8 and P aft = 13.2 (Tetra Bromoethane Fluid - Hydrostatic Pressure Distribution).

3 Ambient temperature will be 70 ± 15°F.

4 160°F for Z5943224 and 110°F for Z5943245.

without damage, delamination or edge separation.

3.2.1.3.2 Edge Attachment. The windshield and edge attachment shall sustain an ultimate load in single shear tension of 870 pounds per inch at a temperature of 225°F.

3.2.1.3.3 Core Ply, Interlayer and Adhesive Systems. The core plies, interlayer material and adhesives, used in the windshield shown on Drawing Z5943245, shall meet the following requirements when tested per Sections 4.1.2.2.2 and 4.1.2.2.4. The test specimen shall be subjected to the same processing temperatures used in the supplier's normal windshield fabrication processes prior to performing the tests.

3.2.1.3.3.1 Core Ply

3.2.1.3.3.1.1 Tensile Properties. The core ply tensile true rupture stress shall be 8500 pounds per square inch minimum, at room temperature, and the true rupture strain shall be 0.45 minimum. These tensile properties shall be demonstrated as noted in Section 4, utilizing tensile specimens made from the core ply test panel and windshield core plies.

3.2.1.3.3.1.2 Core Ply Test Panel . A sheet of material sufficient in size to make the tensile specimens, noted in Section 4, shall be processed concurrently with the core ply of each preproduction and with a sampling of production articles per 4.2.1. This specimen shall be from the same batch lot of material, and identical thickness used for the core ply. The test panel shall receive all of the manufacturer's processes that normally occur during the manufacture of a core ply. These processes shall include drying, curing, press polishing, grinding, coating, all normal surface preparations and multi-axially stretched to a constant thickness identical to the minimum thickness of the core ply.

3.2.1.3.3.2 Interlayer.

3.2.1.3.3.2.1 Shear Strength. The rupture shear strength, at room temperature, shall not be less than 150 psi. This interlayer material

shall not delaminate below this value. Shear properties are to be calculated as shown in 6.9.2.

3.2.1.3.3.2.2 Interlayer Test Panel. A laminated test panel of sufficient size to make the shear test specimens, noted in Section 4, shall be processed concurrently with the full size windshield. This panel shall be laminated from the same batch, lot of material and identical thickness used for the full size transparency laminate. The test panel shall receive all of the manufacturer's processes that normally occur during the manufacturing of the transparency. These processes shall include drying, curing and press polishing for the core ply and face ply materials. All normal surface preparations of the plies shall be accomplished. During the laminating process, the test panel shall receive all of the normal temperatures and pressure requirements for laminating and then be subjected to the same temperature and pressure that would occur during forming of the transparency.

3.2.1.3.3.3 Adhesive. The adhesive, used in bonding the fiberglass phenolic spacer to polycarbonate, shall sustain an average shear strength of 350 pounds per square inch, at 220°F.

3.2.1.3.3.4 Coating. Any coating applied to the surface of the polycarbonate material shall not cause crack propagation when subjected to fatigue loading.

3.2.1.3.3.4.1 Surface Crazing. The surface of the polycarbonate material shall not show surface crazing, that propagate into the polycarbonate material after being subjected to all manufacturing and coating processes. To demonstrate the core ply capabilities, beam specimens shall be prepared from each of the transparencies and tested in accordance with 4.1.2.2.3.

3.2.1.4 Optical. The optical requirements specified herein shall be met after two lifetimes of pressure/temperature cycling defined in Section 4.1.2.2.1 of this specification. Figure 1 defines the three zones where the following requirements shall be met. Zone I is the area that includes the projection of an eight (8) degree half angle cone from the pilot's eye position. The border area, Zone III, shall remain free of any optical requirements unless otherwise specified.

3.2.1.4.1 Luminous Transmittance. The average luminous transmittance of the windshield shall not be less than 60 percent in Zones I and II, when measured at normal angles of incidence to the surface. The luminous transmittance shall not be less than 50 percent when measured at the observer's eye position along a horizontal line with zero azimuth and the windshield in the installed position.

3.2.1.4.2 Haze. The haze in the windshield shall not exceed three (3) percent in Zones I and II at normal angles of incidence.

3.2.1.4.3 Optical Distortion. The distortion shall be determined from photographic prints that contain four indices indicating the horizontal and vertical location of the camera optical centerlines. The distortion values as measured in Section 4.2.2.4 shall be as follows:

a. Lensing or ± magnification shall not exceed ± 8 percent within Zone I.

b. Any apparent bending, blurring, divergency, or convergency of gridlines with the windshield in the installed position shall not exceed ten minutes of arc vertically or horizontally when a common point on the distorted line is evaluated using two photographic prints that represent the left and right eye respectively.

c. The maximum gridline slope shall be 1:15 in Zone I and 1:10 in Zone

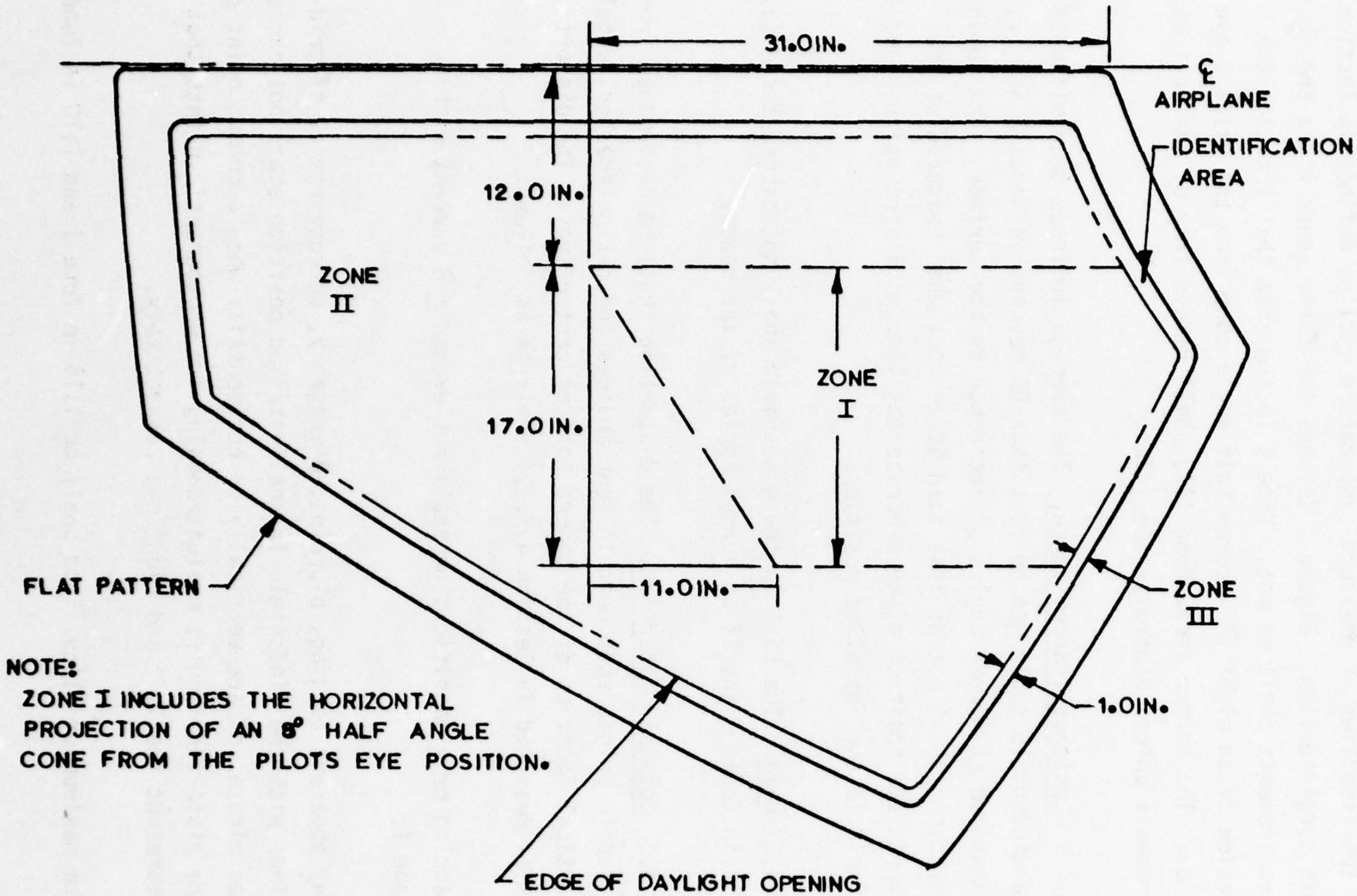


Figure 1. Optical Zoning Requirements.

II when the grid is photographed through the windshield in the installed position. Normal roll-off distortion of 1:1 in Zone III shall not be cause for rejection.

d. The windshield shall be inspected visually as specified in 4.2.4.7. There shall be no immediate apparent bending, blurring, divergency, convergency, or broken gridlines. The total transparency, including the border areas, shall be free of bull's-eye type distortion which causes a distraction to vision.

3.2.1.4.4 Angular Deviation. The angular deviation, when measured normal to the surface, shall not exceed three (3) minutes of arc in Zone I and four (4) minutes of arc in Zone II. The change in direction shall not exceed 180 degrees within any linear 36 inches. With the windshield in the installed position, 15 random points in Zone I shall be selected for the determination of the apparent deviation in elevation and azimuth of each point. The binocular disparity shall not exceed ten (10) minutes of arc between the left and right eye in either the vertical or horizontal direction.

3.2.1.4.5 Optical Defects. Optical defects include scratches, entrapped air, rubs, smears, inclusions and embedded particles such as dirt, lint or other foreign material. Optical defects in the windshield panel shall not exceed the requirements listed in Table 2.

3.2.1.4.6 Birefringency. The rainbow associated with internal stresses developed from manufacturing processing shall be kept to a minimum in Zone II and no rainbowing patterns shall appear in Zone I when the windshield is photographed and visually inspected per Section 4.2.4.6. A color photograph shall be taken from each eye position noted in Section 4.2.2.4. A referee photograph or panel may be established and approved by the procuring agency during the production phase of fabrication. See Appendix V for windshield referee panel selection.

TABLE 2. OPTICAL DEFECT REQUIREMENTS

TYPE DEFECT	MAXIMUM SIZE ALLOWABLE	MAXIMUM NUMBER PER PANEL
1. Scratches	0.020 inch width, 0.005 inch depth and 3 inches in length (see note 2)	Items 1 - 3 Each panel shall be individually evaluated. When the size number, and/or grouping of these type defects cause a distraction to vision or vision impairment, the panel shall be rejected.
2. Lint or Hair	3 inches in length (see note 1)	
3. Smears and Rubs	5/8 inch width or 1-1/2 inch length (see note 1)	
4. Translucent Inclusion or Imbedded Particles	0.125 square inch in area (see note 1)	Items 4 & 5 The total number of these type defects between 0.035 and 0.125 square inch in area for translucent defects or between 0.035 and 0.070 square inch in area for opaque defects shall not exceed twelve (12) per panel. Defects up to 0.035 square inch in area shall be acceptable provided they do not cause vision impairment or visual distraction.
5. Opaque Imbedded Particles and Inclusions	0.070 square inch in area (see note 1)	
6. Surface Crazing	None allowed	

NOTE: Inclusion of defects exceeding the above maximum allowables will be cause for individual windshield evaluation by the procuring agency for possible acceptance.

1. Only in interlayer material.

2. Not on surface of polycarbonate material.

3.2.1.4.7 Color. The yellowness of the core ply mill run of polycarbonate material, prior to fusion bonding, shall be determined and approved by the procuring agency. The yellowness index (YI) for a mill run ply of 0.25-inch thick shall not exceed 8.5 when tested per Section 4.2.4.2.

3.2.1.5 Precipitation Static. The effects of precipitation static shall be controlled by incorporation of the following requirements.

3.2.1.5.1 Resistivity Limits. The anti-static coating shall have a maximum surface resistivity of two megohms per square when tested per Section 4.2.6 and minimum surface resistivity that shall not reduce the uncoated face ply light transmission by more than three percent.

3.2.1.5.1.1 Resistivity Uniformity. The anti-static coating shall be free of voids, which are defined as areas that exceed two megohms per square resistivity when tested per Section 4.2.6.

3.2.1.5.2 Static Drain Path. Static charge deposited on the anti-static coating shall be dissipated as follows.

3.2.1.5.2.1 Anti-Static Drain Bus. A metallic static drain bus bar shall be located on the periphery of the outer surface of the outer face ply. The bus bar shall be fired on the face ply and shall insure continuous contact with the anti-static coating. The resistance of this bus shall not exceed milli-ohms per linear foot as tested by the method of Section 4.2.6.2.1.

3.2.1.5.2.2 Static Drain Strap. The outer metal one-piece, or continuous segments, retainer located around the periphery of the windshield shall provide the electrical continuity between the anti-static drain bus and the structural metal retainer or spacer ring. The retainer shall provide erosion protection for the anti-static drain bus and shall not cause abrasion of the bus due to any relative motion between the retainer and the outer face ply. The resistance of the static drain path from the bus

to the windshield structural metal retainer, or spacer ring, shall not exceed 2.5 milli-ohms. The retainer should have a minimum thickness of 0.032 in. (Section 6.6) to perform adequately as a static drain strap.

3.2.1.5.3 Outer Ply Surface Electrical Isolation. The static drain bus-bar shall be electrically isolated with respect to the anti-ice power feed bus-bar segments and the temperature sensor terminals. The resistance between the static drain bus-bar, the anti-ice power feed bus-bar segments, or temperature sensor terminals shall be greater than 75 megohms.

3.2.1.6 Anti-Icing System. The anti-icing coating, buses and temperature sensing elements, shall be located at the interface of the inboard surface of the outer face ply and the interlayer ply.

3.2.1.6.1 Coating. The daylight opening shall be coated with three (3) segments, A, B and C of conductive film, as shown on Figure 2. Each segment shall be capable of withstanding a maximum power density of 7.15 watts/in.^{2}. Each of the segments shall be powered by the 230 volt line-to-neutral 400 Hz power source, varying between 206 volts and 242 volts. Deletion line width of the coating shall be 0.030 $\pm$ 10 percent inches. The unheated areas, D and E, within the daylight opening shall be coated with the conductive film and shall have the same resistivity as an adjacent heated area. Areas A, B and C shall terminate at peripheral electrical bus-bars defined in Section 3.2.1.6.2. Areas D and E shall terminate at bus-bars defined in Section 3.2.1.7.

3.2.1.6.1.1 Coating Optics. The anti-icing conductive coating shall not reduce the uncoated face ply light transmission by more than five (5) percent.

3.2.1.6.1.2 Coating Uniformity. The coating power density ratios shall be $K_A \geq 0.8$, $K_H \geq 1.3$, $K_C > 0.65$, and $K_M \geq 0.6$ (Section 6.3).

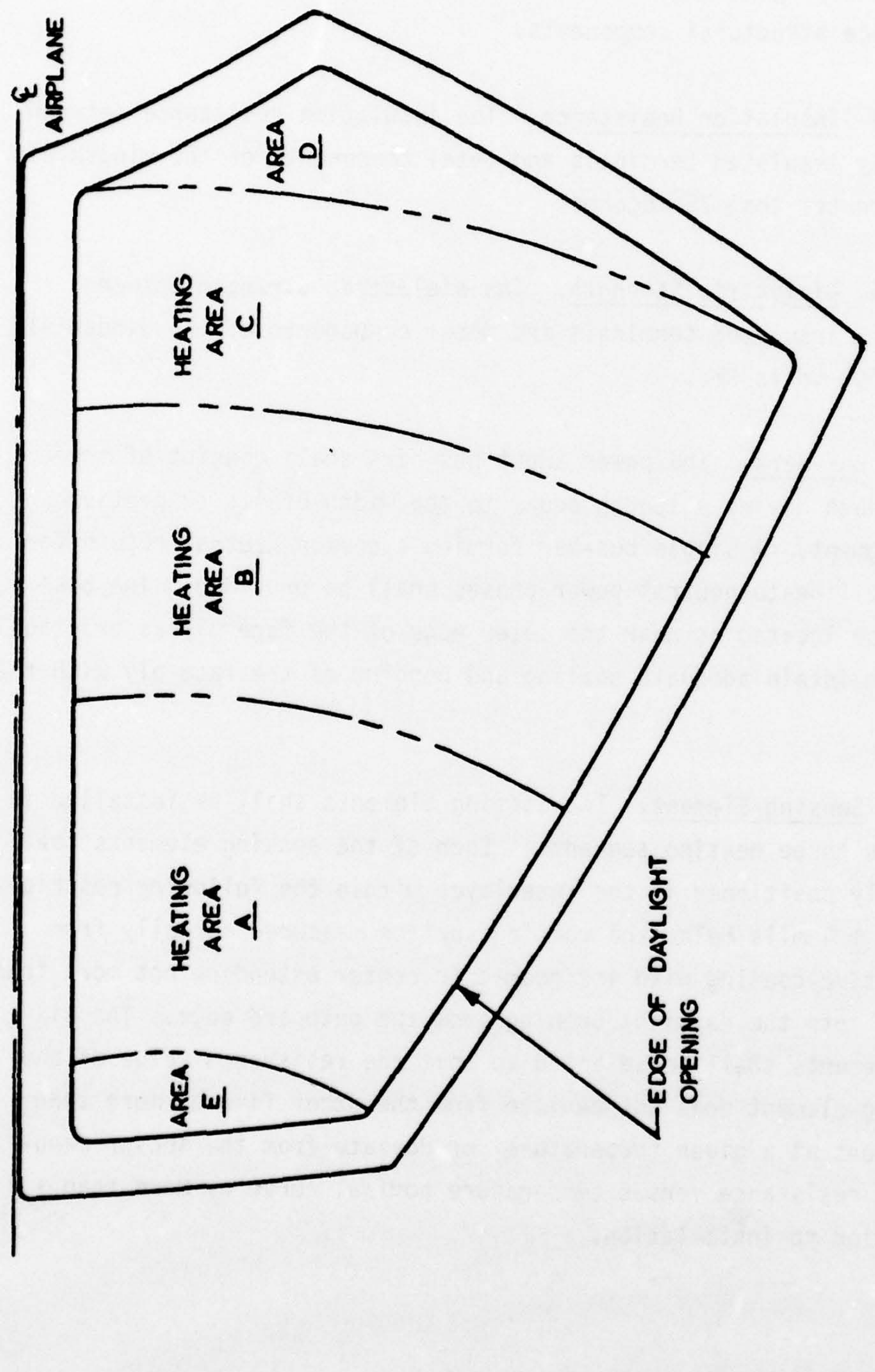


Figure 2. Windshield heating areas.

3.2.1.6.1.3 Over-Voltage. The coating shall meet the over-voltage requirements of MIL-STD-704A for double-voltage systems without evidence of arcing or degradation to the coating, the bus-bar, or any interface structural components.

3.2.1.6.1.4 Insulation Resistance. The insulation resistance between electrically insulated terminals and metal components of the windshield shall be greater than 75 megohms.

3.2.1.6.1.5 Dielectric Strength. The dielectric strength between electrically insulated terminals and metal components of the windshield shall be 2500 volts RMS.

3.2.1.6.2 Bus-Bars. The power input bus-bars shall consist of three segments, each having a length equal to the width of its respective coating segment. A single bus-bar forming a common neutral return for each of the line-to-neutral power phases shall be provided. The bus-bar shall be located as near the outer edge of the face ply as practical, and still maintain adequate sealing and bonding of the face ply with the interlayer.

3.2.1.6.3 Sensing Element. Two sensing elements shall be installed in each of the three heating segments. Each of the sensing elements shall be uniformly positioned in the interlayer within the following restrictions: 40 ± 4 mils below the coating surface measured normally from the conductive coating with its geometric center extending not more than 4.0 inches into the daylight opening from the outboard edge. The six sensing elements shall be selected so that the resistance value of any one sensing element does not deviate from the other five by more than ± 1.0 percent at a given temperature, or deviate from the sensor manufacturer's resistance versus temperature nominal curve by more than ± 1.0 percent prior to installation.

3.2.1.6.4 Bus-Bar and Sensing Element Leads. A total of five (5) bus-bar power leads (one power lead for each of the three bus-bar segments and two for the single common bus-bar neutral return), or equivalent, shall be required. The power leads shall be insulated flexible wire braids with appropriate stress relief at the bus-bar/power lead interface region and within the laminate. A total of 12 solid signal leads for the temperature sensors shall be required. A separate terminal, 17 total, shall be provided for the termination of each sensor, power and neutral lead as shown on the drawing (Section 6.7).

3.2.1.6.5 Electromagnetic Pulse (EMP) Grounding. The EMP interface for the windshield requires a total of eight terminals for EMP grounding functions. One grounding terminal shall be located near each group of four sensor terminals, and one grounding terminal shall be located near each power and neutral terminal as shown on the drawing. The electrical path for these terminals shall satisfy the requirements of Section 3.3.2.4 (Section 6.7).

3.2.1.7 Radar Cross Section Control. Radar cross section control by signal reflection from the windshield shall be accomplished by the anti-icing electrically conductive heating coatings and the coated, but unheated areas, on the internal surface of the outer face ply of the windshields, as shown on Figure 2. The unheated areas, D and E, shall have a separate bus-bar, identical to Section 3.2.1.6.2, around the outer periphery. This bus-bar shall be connected directly to the outer metal retainer.

3.2.2 Environmental Performance. The windshield shall be capable of performance in accordance with the requirements of this specification when subjected to any combination of the environments stated below. "Normal use" type deteriorations are acceptable provided all deteriorations, taken singularly and together, are easily repairable and would not adversely affect the reliability and maintainability requirements of this specification. The requirements of Section 3.2.1.4.1 and 3.2.1.4.2 shall be met before and after testing.

3.2.2.1 Temperatures.

3.2.2.1.1 Ground Storage Temperature. The windshield shall withstand storage temperatures within the range of $-65^{o}F$ to $200^{o}F$.

3.2.2.1.2 Operational Temperatures. The windshield shall withstand temperature profiles within the range of $-80^{o}F$ to $+290^{o}F$ without deterioration.

3.2.2.2 Humidity. The windshield shall withstand the effects of relative humidities up to 100 percent at temperatures up to $150^{o}F$, without cracking, clouding, increase in haze, loss of light transmittance, abrasion resistance, or adhesion.

3.2.2.3 Fungus Resistance. The windshield shall be capable of withstanding exposure to fungus growth as encountered in tropical climates. All fungus nutrient materials other than those used in hermetically sealed assemblies shall be treated in such a manner as to prevent fungus growth.

3.2.2.4 Salt Atmosphere. The windshield shall be corrosion resistant or so processed as to withstand salt spray when the transparency is in the "as installed" condition.

3.2.2.5 Sunshine. The windshield shall not be affected by prolonged exposure to simulated sunlight or natural sunlight. The natural sunlight test exposure time shall be representative of the reliability requirement of Section 3.2.3. A maximum of 1 percent haze increase at the conclusion of test may occur before rejection.

3.2.2.6 Solvents and Solutions. The exposed surfaces installed and under storage conditions shall be capable of withstanding exposure to solutions commonly used in the operational and maintenance environments without degradation. The following list of solutions shall be used and shall not be considered as a restrictive list.

a. Mild soap and water.
b. Airplane wash cleaner fluid (MIL-D-8514).
c. Phosphoric acid cleaner (A-3) (MIL-C-5410).
d. Alodine 1200 spray and rinse (MIL-C-5541).

e. Bug remover fluid (P6009).
f. Rain repellant fluid (Rapcon, FSN 6850-139-5297).
g. Naptha.
h. Jet fuel (JP-4).
i. Isopropyl alcohol.
j. De-ice fluid (ethylene glycol type).

3.2.2.7 Abrasion. The surfaces shall withstand sustained abrasion from normal cleaning as well as rain impingement up to Mach 0.85 at sea level per testing requirements noted in Section 4.1.2.3.5.6.

3.2.3 Reliability. The windshield shall be constructed to perform satisfactorily for a design minimum of 5,000 hours MTBR (Mean Time Between Replacement) per panel.

3.2.4 Maintainability. The windshield shall be of such quality that damage is not incurred due to cleaning normally performed on a daily basis nor shall there be a need for special cleaning agents other than mild soap and water solutions. Special tools or equipment shall not be required for handling. Provisions for hoisting with standard equipment shall be provided. The windshield shall be constructed to perform satisfactorily for a design goal of .008 maintenance manhours per flight hour.

3.3 Design and Construction.

3.3.1 Production Drawings. The windshield shall be fabricated and assembled in accordance with the drawings, parts lists and other documents listed on Drawing Z5943224 or Drawing Z5943245 as specified by the procuring agency.

3.3.1.1 Interchangeability. All parts having the same part numbers shall be functionally and dimensionally interchangeable as specified in MIL-E-8500.

3.3.1.2 Environmental. The materials used and the product design shall meet the environmental requirements specified in Section 3.2.2. The edges of the polycarbonate material shall be totally protected from environmental exposure.

3.3.2 Standards of Manufacturer.

3.3.2.1 Selection of Specifications and Standards. Specifications and standards for necessary commodities and services not specified herein shall be selected in accordance with MIL-STD-143.

3.3.2.2 Materials. Selection of materials shall be made with special attention being given to the requirements of temperature, temperature change, loads, and other environmental conditions. Attention shall also be given to reliability, repairability and lightweight construction. When necessary to use other than standard materials, the supplier shall base his selection on tests to prove suitability for the intended purpose. Test plans to assure quality control of all components that form a part of these assemblies shall be submitted to the procuring agency for approval.

3.3.2.3 Protective Treatment. The final assembly, when materials are used in the construction of the windshield that are subject to handling, shipping or installation damage, or deterioration when exposed to climatic and environmental conditions likely to occur during service usage, shall be protected against such deterioration in a manner that will in no way prevent compliance with the performance requirements of this specification.

3.3.2.4 System Interface. The windshield shall be compatible with the envelope of the crew module structurally and electrically.

3.3.2.4.1 Electrical Requirements. The temperature requirements of Section 3.2.1.3 shall be verified and the tests in Sections 4.1.2.3

and 4.2.6 shall be performed using the procuring agency approved B-1 aircraft electrical controller (Part Number TBD) or its electrical equivalent.

3.3.2.4.1.1 Electrical Power. The anti-icing system shall be powered by an electrical power controller input (not covered by this specification). This is derived from a 230/400 volts, 400 Hz electrical power system.

3.3.2.4.1.2 Electrical Terminals. The power, sensing element and EMP ground terminal blocks shall be located as shown on the windshield, Drawing Z5943245 and Drawing Z5943224. The terminals shall be capable of withstanding a 100-pound tension load applied perpendicular to the panel surface and a torque load of 50 inch-pounds without failure. The windshield design shall include provisions for clamping the vehicle wiring harness, Drawing Z5943242, to the assembly along the inside lower surface in the area of the terminals.

3.3.2.4.2 Hoisting Provisions. The windshield hoisting provisions shall consist of four internally threaded plugs as shown on the drawings. Each plug shall withstand a 250-pound tension load applied perpendicular to the panel surface and a torque load of 200 inch-pounds without failure.

3.3.2.4.3 Electromagnetic Pulse Suppression (EMP). The windshield design shall provide the EMP suppression interface (Section 6.7) as follows:

3.3.2.4.3.1 Sensor Leads. The sensor leads, within the windshield, shall be as short as possible and shall be routed as close together as is practicable.

3.3.2.4.3.2 EMP Ground Terminals. The electrical paths from the EMP ground terminals, Section 3.2.1.6.5 shall be as short as possible to

the windshield metal retainers. The direct-current resistance of each of these paths shall not exceed 2.5 milli-ohms.

3.3.2.5 Weight. The weight of the windshield exclusive of attachment bolt hardware shall not exceed 145 pounds for a plastic, or 205 pounds for a glass windshield.

3.3.2.6 Dimensional Inspection of Product. The windshield panel dimensions and dimensional tolerances shall be as specified herein and in Drawing Z5943245 or Drawing Z5943224.

3.3.2.6.1 Hole Alignment. All holes will be checked with the windshield clamped to fixture using Part Number (TBD) pins.

3.3.2.6.2 Trim Size. With the windshield clamped to the trim fixture, the edge of the windshield shall be within $^{+0.00}_{-0.06}$ inch of edge of fixture around periphery.

3.3.2.6.3 Surface Finish. The mounting holes and trim edges shall be finished to a 90 micro-inch RMS finish or better for polycarbonate materials, and 125 micro-inches or better for glass laminated materials.

3.3.2.6.4 Contour, Clamped. The edging shall not deviate more than 0.010 inch from the contour at any point along the periphery of the windshield with the panel clamped to the contour fixture, after torqueing all bolts to 20-30 inch-pounds. Deviation from the nominal lofted mold line shall be no greater than 0.030 inch.

3.3.2.7 Identification of Product. Identification amd marking shall be in accordance with MIL-STD-130 and shall include the following:

This identification and marking shall be permanently affixed to the windshield in a position from which it shall be easily read when installed on the aircraft. Figure 1 shows the approximate location

of the identification and marking.

Part Number and Change Letter
Procuring Agency's Specification Number and Change Letter
Manufacturer's Serial Number
Manufacturer's Name or Trademark
Manufacturer's Code Identification Number
Manufacturer's Lot Number
Date of Manufacture
Weight
Federal Stock Number

3.3.2.8 Lot Definition. A lot shall consist of the number of windshields that will be ordered in any given year from an individual manufacturer.

3.3.3 Workmanship. The uniformity and general appearance of the transparencies shall be of the highest quality for this type product. The panels shall be clean, free of foreign matter, free of sharp edges, and drilled holes shall be free of burrs.

3.3.4 Certification. Concurrent with each shipment, the vendor shall supply certification to the procuring agency in writing for each acceptance test specified in this document. Test results deviating from specification requirements shall be submitted to material review record action in accordance with 4.2.10.

3.4 Preproduction. Full size preproduction samples of the windshield shall consist of those panels tested in accordance with Section 4.1.2, prior to approval for production by the procuring agency, to demonstrate the adequacy and suitability of the manufacturer's materials and processing in achieving the required product performance specified herein. Except as approved by the procuring agency, the preproduction samples shall meet the requirements of this specification. The preproduction

samples shall be as specified by the procuring activity, or Section 4.1.2. The preproduction tests shall be initiated by the procuring agency at any time the production quality control tests for Section 3.2.1.3.3 are not met.

3.5 Design Changes. Modification of the design, materials, or fabrication processes for the windshield shall not be made after completion of the preproduction tests without the review and approval of the procuring agency.

4. QUALITY ASSURANCE PROVISIONS

4.1 General. The preproduction testing specified herein shall be performed either by the procuring agency or by the supplier at test facilities approved by the procuring agency. Production fabrication acceptance testing specified herein shall be performed by the manufacturer. The manufacturer shall prepare a test plan or plans describing his approaches to meeting the testing requirement specified herein. Each test plan shall be approved by the procuring agency prior to the initiation or preproduction and production tests and initiation of production.

4.1.1 Responsibility for Inspection. Unless otherwise specified in the contract or order, the manufacturer is responsible for the performance of all inspection requirements specified herein. Except as otherwise specified, the manufacturer may utilize his own facilities or any commercial laboratory acceptable to the procuring agency. The procuring agency reserves the right to perform any of the inspections or tests set forth in this specification where such inspections and separate tests are deemed necessary to assure that the product critical item conforms to prescribed requirements.

TABLE 3. PREPRODUCTION AND ACCEPTANCE TESTS

DESCRIPTION	REQUIREMENT	TEST PROCEDURE	
		PREPRODUCTION	ACCEPTANCE
Impact Resistance	3.2.1.1	4.1.2.1(1)	
Hail Impact	3.2.1.2	(TBD)	
Structural Integrity	3.2.1.3	4.1.2.2 (1)	
Accelerated Environmental	3.2.1.3	4.1.2.2 (1)	
Temperature (Production)	3.2.1.3		4.2.1.1
Proof Pressure	3.2.1.3	4.1.2.2	4.2.1.2
Edge Attachment	3.2.1.3	4.1.2.4(2)	4.1.2.4(2)
Core Ply Interlayer & Adhesive System	3.2.1.3	4.1.2.2	4.1.2.2(2)
Optical Properties	3.2.1.4	4.2.4(1)	4.2.4
Precipitation Static	3.2.1.5	4.2.6	4.2.6
Anti-Ice	3.2.1.6	4.2.7	4.2.7
Radar Cross Section	3.2.1.7	4.2.6	4.2.6
Temperature	3.2.2.1	4.1.2.3(2)	
Humidity	3.2.2.2	4.1.2.3(2)	
Fungus	3.2.2.3	4.1.2.3(2)	
Salt	3.2.2.4	4.1.2.3(2)	
Sunshine	3.2.2.5	4.1.2.3(2)	
Solvents and Solutions	3.2.2.6	4.1.2.3(2)	
Abrasion	3.2.2.7	4.1.2.3(2)	
Interface - Terminals	3.3.2.4.2	4.2.1.3	4.2.1.3
Interface - Hoist	3.3.2.4.3	4.2.1.4	4.2.1.4
Weight	3.3.2.6	4.2.8	4.2.8
Inspection of Product	3.3.2.7	4.2.9	4.2.9
Identification	3.3.2.8	4.2.9	4.2.9

(1) Tests are to be performed by the procuring agency on preproduction hardware.

(2) Tests are to be performed on samples by the supplier. The proof of compliance for all other requirements is the responsibility of the supplier.

4.1.2 Special Tests and Examinations. The windshield shall be subjected to the preproduction and acceptance tests specified in Table 3 and the specified requirements of Section 3. Table 4 is a listing of the specimens required for the bird impact and accelerated environmental tests. This table identifies two transparency configurations of which the procuring agency may select one or both transparencies for bird impact and environmental testing.

4.1.2.1 Bird Impact Tests. A minimum of five (5) complete windshields shall be subjected to bird tests as described in Section 10 of this specification per requirements in Table 4. A minimum of two of these transparencies must have completed two lifetimes of environmental (pressure and temperature) and optical evaluation tests prior to bird impact testing.

4.1.2.2 Structural Integrity Tests.

4.1.2.2.1 Accelerated Environmental Tests. The two windshields required for 4.1.2.1 plus one additional complete windshield system shall be subjected to two (2) lifetimes of accelerated environmental tests as specified in Section 20 of this specification. One of these windshields shall be subjected to proof pressure and then ultimate design pressure tests after completion of optical evaluation tests have been completed.

4.1.2.2.2 Core Ply Integrity - Validation/Verification Tests. Test specimens shall be made from the core ply test panels noted in Section 3.2.1.3.3.1.2 and each Z5943245 windshield after completion of bird impact tests. These specimens will be subjected to the following tests under uniform testing conditions.

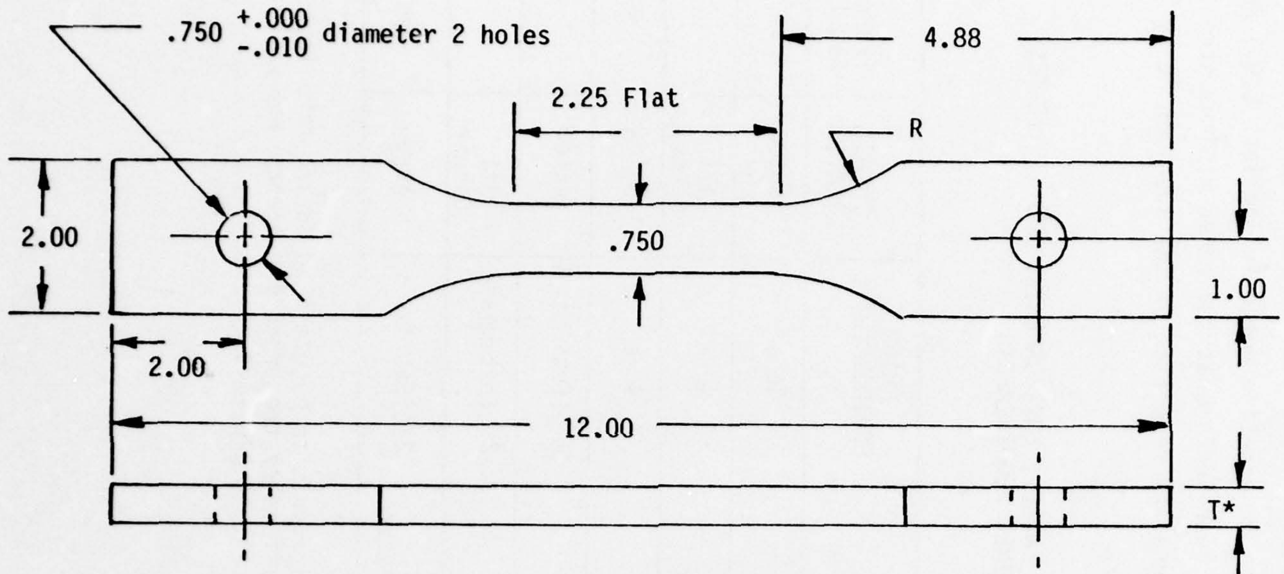
4.1.2.2.2.1 Core Ply Test Panel Tensile Tests. A minimum of five specimens taken from each core ply test panel noted in Section 3.2.1.3.3.1.2 shall be fabricated in accordance with Figure 3 and ASTM-D638. The specimens shall be tested in tension on a suitable approved test machine with a cross-head travel of 0.05-inch per minute at room temperature. The minimum

true tensile rupture stress for the five specimens in pounds per square inch shall be 8500 or greater and the minimum true rupture strain shall be 0.45 as calculated from the equation noted in Sections 6.9.1 and 6.9.3. Delaminations at a fusion bond surface at the above minimum stress or strain values shall be cause for rejection of the specimen as well as the full size transparency.

TABLE 4. BIRD IMPACT, ENVIRONMENTAL AND STATIC TEST SPECIMEN REQUIREMENTS

SPECIMEN NO.	FINAL TEST	PRIOR ENVIRONMENTAL	IMPACT LOCATION	TEMPERATURES REQUIREMENTS
1	Bird Impact	None	Center	Hot
2	Bird Impact	None	Aft Corner	Cold
3	Bird Impact	None	Choice	Ambient
4	Bird Impact	2 Lifetimes	Center	Hot
5	Bird Impact	2 Lifetimes	Aft Corner	Hot
6	Proof Pressure & Ultimate Pressure	2 Lifetimes	None	Ambient

NOTE: The specific temperatures to be utilized during bird impact testing will be defined by the procuring agency and shall be representative of flight profiles.



*Specimen shall be stretch formed to equal the minimum transparency thickness.

Specimen per ASTM-D638 Type III

Figure 3. Tension Specimen - Core Ply.

4.1.2.2.2.2 Impacted Transparency Core Ply Tensile Tests. After completion of all of the bird impact tests and the accelerated environmental tests, ten tensile specimens shall be fabricated from each of the six (6) windshields at the locations noted in Figure 4 to the shape as noted in Figure 3 and ASTM-D638. Each tensile specimen shall have the outer ply and the interlayer removed and core plys separated. These tensile specimens shall be tested on an identical test machine as noted in Section 4.1.2.2.2.1. In the event that the specimens from Windshield No. 1 (Table 4) does not meet the minimum requirements of 8500 psi true rupture stress and 0.45 true rupture strain as calculated from the equations noted in Section 6.9.1 and 6.9.3 but does pass the impact test requirements, then the manufacturer must determine new minimum requirements based on methods described in Section 6.9.4. The full-size windshield and the core ply test panel specimens for windshield No. 1 (Table 4) are to be compared per methods described in Section 6.8.5. The remainder of the windshield core ply tensile tests, numbers 2 through 4 , shall be compared to tensile results of the core ply from windshield No. 1 (Table 4) to determine effects of environmental conditioning to provide data for establishing final reliability requirements noted in Section 4.3. The remainder of the core ply test panel tensile tests shall be compared to No. 1 (Table 4) core ply test panel tests per methods described in Section 6.9.5 to determine consistency of core ply test panel processing.

4.1.2.2.3 Core Ply Surface Effects. It is mandatory that the processing primers, interlayer, and coatings do not attack the polycarbonate core ply. Neither immediate or latent attack can be tolerated. Any etching, crazing or cracking of the polycarbonate interface that could significantly reduce the impact resistance of the windshield shall be cause for rejection.

4.1.2.2.3.1 Core Ply Test Panel Surface Effects Tests. From each test panel noted in Section 3.2.1.3.3.1.2 make one (1) beam 2-1/2 inches wide by 12 inches in length, as shown in Figure 4, and setup a bending test per Figure 5. Apply an increasing load on the beam until failure occurs. Investigate both surfaces of the beam to ascertain the degree

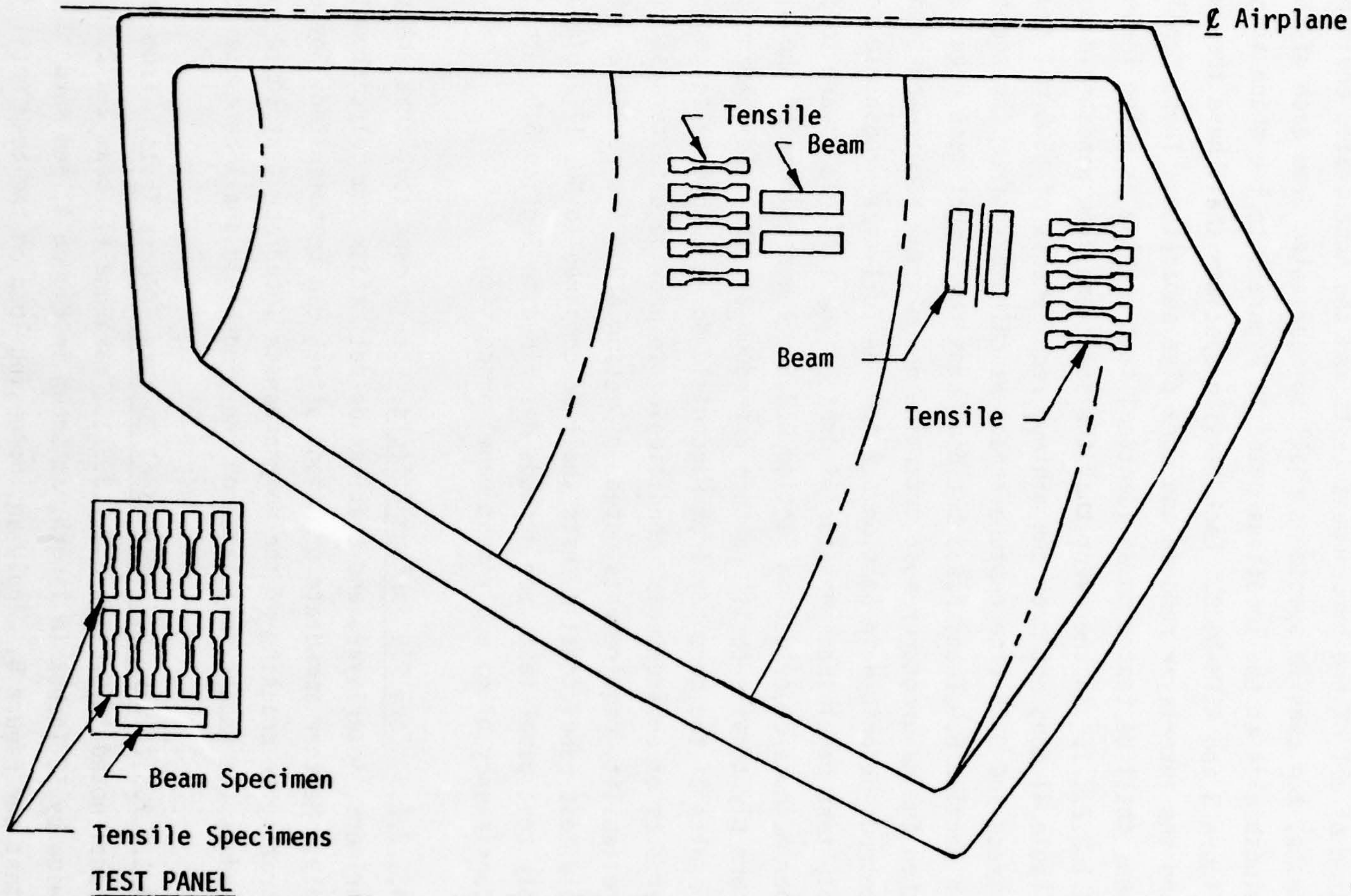
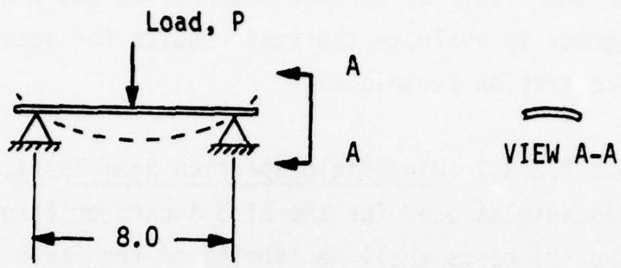


Figure 4. Core Ply Test Specimen Location.



Test Series -1 run with + P. (normal bending)

Test Series -2 run with - P. (reverse bending)

Load, P, applied at maximum crosshead rate of 20 in./min.

Deflection, Δ, measured at load point.

Test Series -3 run with increasing load to failure.

Figure 5. Canopy Beam Bending Test Orientation and Specimen Location.

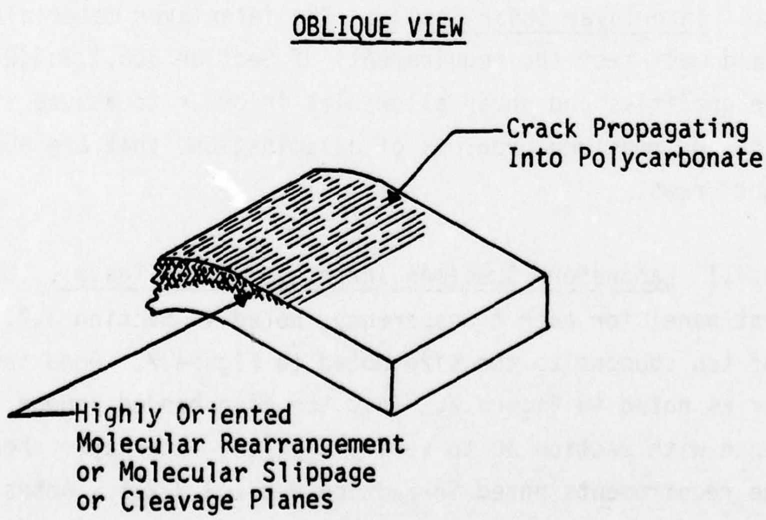


Figure 6. Section Removed from the Ruptured Beam Test Specimen Prepared for Microscopic Examination.

of cracking/crazing/fissures developed in the ruptured area as noted in Figure 6. Any evidence of cracking instigated by pre-test coating cracks or the result of surface preparation shall be cause for the procuring agency to evaluate the test results for acceptance of coating surface preparation techniques.

4.1.2.2.3.2 Windshield Specimen Beam Tests. From each of the six (6) windshields used for the bird impact or accelerated environmental tests, two (2) beams shall be fabricated from each windshield using the core ply material only to make specimens of 2-1/2 inches wide by 12 inches in length as shown in Figure 3. Extreme care shall be taken when removing the outer ply and interlayer material not to remove or damage the prepared and/or coated polycarbonate surface. Test in accordance with Figure 5. Any evidence of cracking instigated by pre-test coating cracks or surface preparation shall be cause for the procuring agency to review the test results for acceptance of coating surface preparation techniques.

4.1.2.2.4 Interlayer Shear Tests. The interlayer materials used in the windshield must meet the requirements of Section 3.2.1.3.3.2 both for adhesive qualities and shear allowables in order to assure structural integrity and preclude problems of delaminations that are objectionable to flight crews.

4.1.2.2.4.1 Laboratory Specimen Interlayer Shear Tests. Utilizing the core test panel for each transparency, noted in Section 3.2.1.3.3.1.2, cut a set of ten coupons to the size noted in Figure 7. Bond two coupons together as noted in Figure 7. Test the five bonded coupon assemblies in accordance with Section 30 to verify that the interlayer shear allowables meet the requirements noted in Section 3.2.1.3.3.2.1. Adhesive bond failure below the specified values of the interlayer to the adjacent plies shall be cause for rejection.

4.1.2.3 Materials and Processes. The manufacturer shall perform sample tests which will assure adequate control of the materials and processes

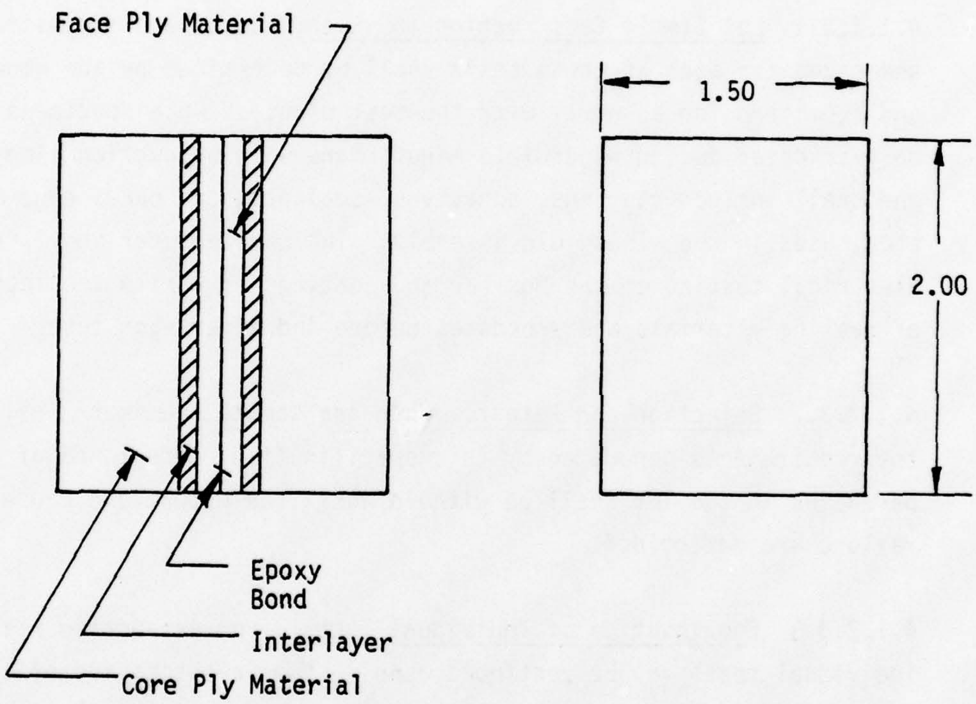


Figure 7. Shear Specimen - Interlayer.

used in construction of the transparencies. The supplier's test plan shall be submitted to the procuring agency for approval prior to production. The test plan shall also include manufacturer documentation of prior tests performed that could potentially meet the requirement for, or the intent, of any preproduction test in this section.

4.1.2.3.1 Lot Sample Construction and Size. Lot, sample construction and sizes for each of these tests shall be determined by the manufacturer and submitted for approval with the test plan. Sample specimens shall be fabricated during windshield manufacture with production line personnel and shall include coatings, adhesives, sealants, bus bars, edge materials, etc., used in the windshield assembly. The manufacturer shall include electrical testing of the bus-bar and coatings to verify the integrity of sealing materials and processes before and after each test.

4.1.2.3.2 Rejection and Retest. When one sample specimen fails to meet the requirements generated by this specification, acceptance of all transparencies in the lot shall be witheld until the extent and cause of failure are determined.

4.1.2.3.3 Continuation of Individual Tests. For production reasons, individual tests may be continued pending the investigation of a sampling test failure. But final acceptance of the entire lot shall not be made until it is determined that the lot meets the requirements generated by this specification.

4.1.2.3.4 Defects in Items Already Accepted. The investigation of a test failure could indicate that defects may exist in items already accepted. If so, the supplier shall fully advise the procuring agency of all defects likely to be found and a method of correcting them.

4.1.2.3.5 Sample Tests. The representative sample specimens of the approved design shall be subjected to the following environmental

exposures. The requirements of Section 3.2.2 shall be met. The normal transmission and haze requirements of Section 3.2.1.4 shall be met before and after each test.

4.1.2.3.5.1 <u>Fungus</u>. Conduct tests in accordance with MIL-STD-810, Method 508, Procedure I. If the materials used are certified non-nutrient to fungus, the test may be omitted.

4.1.2.3.5.2 <u>Humidity</u>. Conduct tests in accordance with MIL-STD-810, Method 507, Procedure V. The temperature for Step 4 shall be changed to 65.6^{o}C (150^{o}F). Step 5 shall be deleted and the maximum humidity in Step 7 shall be increased to 100%.

4.1.2.3.5.3 <u>Salt Spray</u>. Conduct tests in accordance with MIL-STD-810, Method 509, Procedure I.

4.1.2.3.5.4 <u>Sunshine</u>.

4.1.2.3.5.4.1 <u>Test I</u>. Conduct tests in accordance with MIL-STD-810, Method 505, Procedure 1.

4.1.2.3.5.4.2 <u>Test II</u>. Conduct natural sunshine exposure tests equivalent to five years exposure in Arizona. Accelerated natural exposure testing may be used where approved by the procuring agency.

4.1.2.3.5.5 <u>Chemical Crazing Resistance</u>. Conduct crazing resistance tests in accordance with an approved manufacturer's test using the fluids of 3.2.2.6 of this specification.

4.1.2.3.5.6 <u>Abrasion</u>.

4.1.2.3.5.6.1 <u>Ground Service</u>. Conduct 1000 simulated cleanings of the transparency using supplier recommended cleaning fluid and wiping material. (Both must be standard Air Force FSN materials. Reference Scratch Standard ASTM F418).

4.1.2.3.5.6.2 Flight Exposure. Conduct rain impingement tests at Mach 0.85 on test specimens inclined at 25 degrees to the direction of the motion. The rate of simulated rainfall shall be a minimum of 0.6-inch per hour. Continue testing for four hours maximum or until the external surface coating loss is evident or another maximum time specified by the procuring agency.

4.1.2.4 Edge Attachment. A minimum of five edge attachment test specimens per windshield shall be fabricated as illustrated in Figure 8. The materials used and processing shall be identical to that used for fabricating the production windshield edge attachments. The test specimen shall be tested to failure at a soak temperature of $225^{o}F \pm 5^{o}F$ on a suitable tensile test machine. The rate of loading shall be 0.05 inch per minute of test machine cross-head travel. The test results shall be reported in pounds per inch ultimate tension and shall exceed 870 pounds per inch.

4.2 Quality Conformance Inspection. The manufacturer shall prepare detail inspection and functional test plans for the performance and conformity verification tests defined in this section. The detailed test plans, procedures, list of applicable test equipment and calibration procedures shall be submitted to the procuring agency for approval. To meet the requirements of Section 3, the supplier's preproduction windshield and/or materials specimens shall be subjected to the testing requirements noted in Sections 4.1.2.1, 4.1.2.2 and 4.1.2.3 and subsections contained therein, plus each transparency fabricated must meet the conformance inspection requirements specified in subsequent paragraphs. Production parts, if approved, shall also meet the testing specified in Sections 4.1.2.1, 4.1.2.2 and 4.1.2.3 and the subparagraphs contained therein plus each of the conformance inspection requirements specified in subsequent subparagraphs until a total of ten consecutive parts have been fabricated.

4.2.1 Sampling Plan. After a windshield design has been approved by the procuring agency, and the manufacturer has demonstrated that his

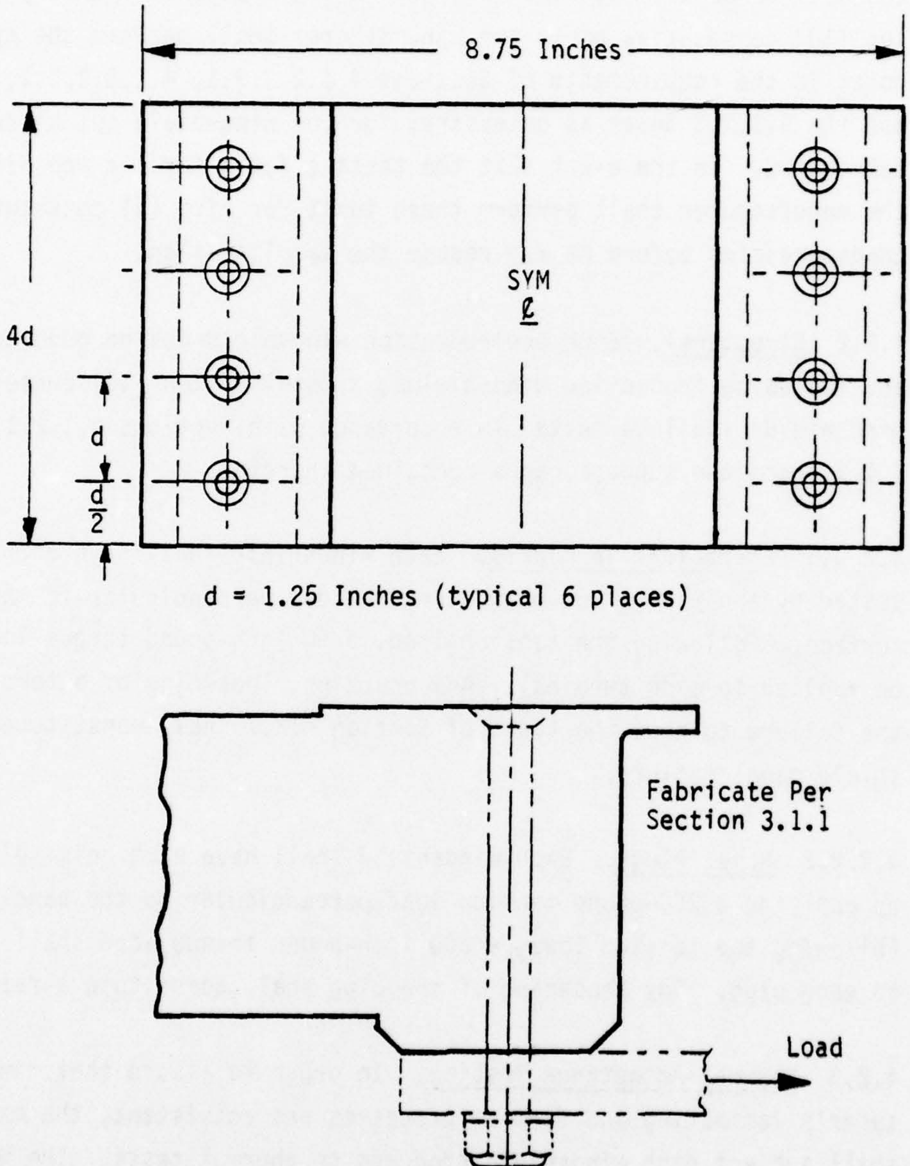


Figure 8. Edge Attachment - Tensile Specimen.

manufacturing processes and methods are consistent for a minimum of ten (10) consecutive parts, then the manufacturer may follow a sampling plan. After ten (10) consecutive parts the manufacturer shall perform the special tests noted in the requirements of Sections 4.1.2.2.2.1, 4.1.2.2.3.1, 4.1.2.2.4.1 and the 4.1.2.3 tests as necessary, for one windshield out of ten (10) fabricated. In the event that the testing fails for the one windshield then the manufacturer shall perform these tests for five (5) consecutive transparencies before he may resume the sampling plan.

4.2.2 Structural. Each preproduction windshield design produced up to and including production windshields, a total of ten (10) consecutive windshields shall be tested in accordance with Sections 4.1.2.1, 4.1.2.2, 4.1.2.3 and the subparagraphs contained therein.

4.2.2.1 Electrical Terminals. Each windshield shall have each terminal tested by applying a 100-pound tension load perpendicular to the panel surface. Following the tension load, a 50 inch-pound torque load shall be applied to each terminal. Any cracking, loosening of a terminal, or the failure to pass the tests of Section 4.2.7 shall constitute a windshield panel failure.

4.2.2.2 Hoist Plugs. Each windshield shall have each hoist plug tested by applying a 250-pound tension load perpendicular to the panel surface. Following the tension load, a 200 inch-pound torque load shall be applied to each plug. Any loosening of the plug shall constitute a failure.

4.2.3 Thermal Acceptance Testing. In order to assure that the manufacturer's laminating and forming processes are consistent, the manufacturer shall subject each windshield produced to thermal tests. The windshield shall be placed in a cold box, that has a controlled temperature of -65°F, for one hour or until the core ply reaches at least -20°F. Remove the windshield from the cold box and within five (5) minutes, apply electrical power to the three heating areas simultaneously, using a 200 volt line-to-neutral 400 Hz power source. The power to each area shall be applied

gradually from 0 to 230 volts over a four (4) minute period and control point temperature set at 110^{o}F. Allow windshield to return to room temperature. Place the windshield in an oven of dry circulating air and hold for one hour or until the core ply surface temperature is a maximum of +160^{o}F. Repeat these temperature cycles five times for each windshield fabricated. Delamination of the interlayer or adhesive failure of the edge member shall be cause for rejection.

4.2.4 <u>Optical Requirements</u>. The manufacturer shall perform optical evaluation tests on each transparency per the procedures detailed in Section 40 of this specification to the requirements in Section 3.2.1.4 and as specified herein.

4.2.4.1 <u>Luminous Transmission and Haze</u>. The luminous transmittance and haze of the windshield shall be determined in accordance with ASTM-STD-D1003. A minimum of 20 measurements shall be made on each windshield in Zone I. The measurements in Zone II shall be taken at points on a grid spaced not more than ten (10) inches apart. Luminous transmission and haze shall be measured at the same location. Luminous transmission and haze shall be reported as the average of the measurements in each zone. The luminous transmission for the installed position shall be measured as required in Section 3.2.1.4.1 and reported with the above.

4.2.4.2 <u>Anti-Static Coating Luminous Transmission</u>. The three percent reduction in light transmission specified in Section 3.2.5.1 for the minimum surface resistivity limit shall be determined using sample size specimens coated by production line personnel. The shape and size of the specimens shall be determined by the manufacturer. The specimen base material shall be the same thickness used in the production article. The following procedure shall be used:

a. Prepare three specimens: (1) an uncoated reference specimen, (2) a coated specimen for maximum resistivity and (3) a specimen coated for minimum resistivity that will be indicative of the suppliers manufacturing process.

b. Measure and record the surface resistivity per square of the coated specimens.

c. Measure the light transmission, per Section 4.2.4.1, of each specimen.

d. The difference in light transmission between specimen (1) and specimen (3) shall be less than three percent of the light transmission value for specimen (1).

e. The difference between specimens (1) and (2) shall be recorded as the minimal light loss through the anti-static coating.

f. Specimens shall be prepared and tested with each preproduction article and every tenth production article thereafter.

4.2.4.3 Anti-Ice Coating Luminous Transmission. The five percent reduction in light transmission specified in Section 3.2.1.6.1.1 shall be determined using sample size specimens coated by production line personnel. The shape and size of the specimens shall be determined by the manufacturer. The specimens shall be a three-ply laminate using face plies, first interlayer and core ply the same as in the production article, as to both material and thickness. The following test procedure shall be used:

a. Prepare two specimens: (1) an uncoated reference specimen, (2) a specimen coated on the inner surface of one face ply.

b. Measure and record the electrical characteristics of the coated specimen.

c. Measure the light transmission, per Section 4.2.4.1, of each specimen.

d. The difference in light transmission between specimen (1) and (2) shall be less than five percent of the light transmission for specimen (1).

e. Specimens shall be prepared and tested along with each preproduction article and every tenth production article thereafter.

4.2.4.4 Color. The requirements of Section 3.2.1.4.7 shall be verified using test coupons prepared from the mill run material used in the fusion bond lamination procedure for the core ply of the transparency. These coupons shall be tested per ASTM-D-1925 to determine the yellowness index (YI). The coupons shall then be processed by the manufacturer into cross-sectional specimens of the final transparency. The yellowness index (YI) of the final laminated specimens shall be determined by the manufacturer. The difference ΔYI shall be determined by the manufacturer and approved by the procuring agency. These cross-sectional specimens, upon approval, may be retained and used for color referencing full scale transparencies. The cross-sectional specimens are not required to meet the $YI_0 = 8.5$ specified in Section 3.2.1.4.7.

4.2.4.5 Optical Distortion. Distortion of the windshield shall be tested per the method described in Section 40.

4.2.4.5.1 Physical Requirements.

4.2.4.5.1.1 Windshield Position. The windshield shall be positioned as shown in Figure 10 to accomplish the tests.

4.2.4.5.1.2 Photographs. Three (3) photographs shall be taken of each preproduction windshield per Section 40 at locations shown in Figure 10 and Table 5. One control photograph shall be taken of the grid only from the design eye point for subsequent comparisons to the photographs taken through windshields.

4.2.4.5.2 Distortion Analysis. Verify that Section 3.2.1.4.3 requirements have been accomplished as outlined by the procedure in Section 40.

4.2.4.5.3 Grid Line Slope. Using the procedure detailed in Section 40 verify that the requirements of Section 3.2.1.4 were not exceeded.

4.2.4.5.4 Visual Inspection. The transparency shall be mounted on the applicable holding fixture and positioned in relation to the optical grid as shown in Figure 9. The observer shall view the grid through the transparency from the pilot's or co-pilot's eye position. The complete transparency shall be inspected for sharpness, bending, blurring, divergency, convergency, or broken grid lines not detected in Section 4.2.4.5. The part shall also be viewed in ambient sunlight from the design eye position against the distant moving objects. Any areas producing distractive distortion of the grid lines, or distractive changes in object shape of motion, shall be marked and tested per Section 4.2.4.5.

4.2.4.6 Angular Deviation. The angular deviation and direction shall be mapped approximately 5-inch squares over Zones I and II per ASTM-D-881 using concentric circles whose radii increase in steps equal to one minute of arc. The requirements of Section 3.2.1.4.4 shall not be exceeded.

4.2.4.7 Optical Defects. The transparency shall be examined for optical defects, by viewing a dark background illuminated by blue-white fluorescent lights through the transparency. The transparency shall be viewed from 24 to 36 inches from the transparency. The area of defects detected by this technique shall be measured using an optical comparator and the size and location of the defects shall be recorded. (Reference: ASTM-D-F428 proposed.)

4.2.4.8 Birefringency. The rainbowing associated with internal stresses and variation of individual ply thickness shall be determined for each transparency during the preproduction phase using a light source having approximately 80 percent skylight polarization. A color photograph shall be taken from each eye position noted in Section 4.2.4.5. A referee photograph

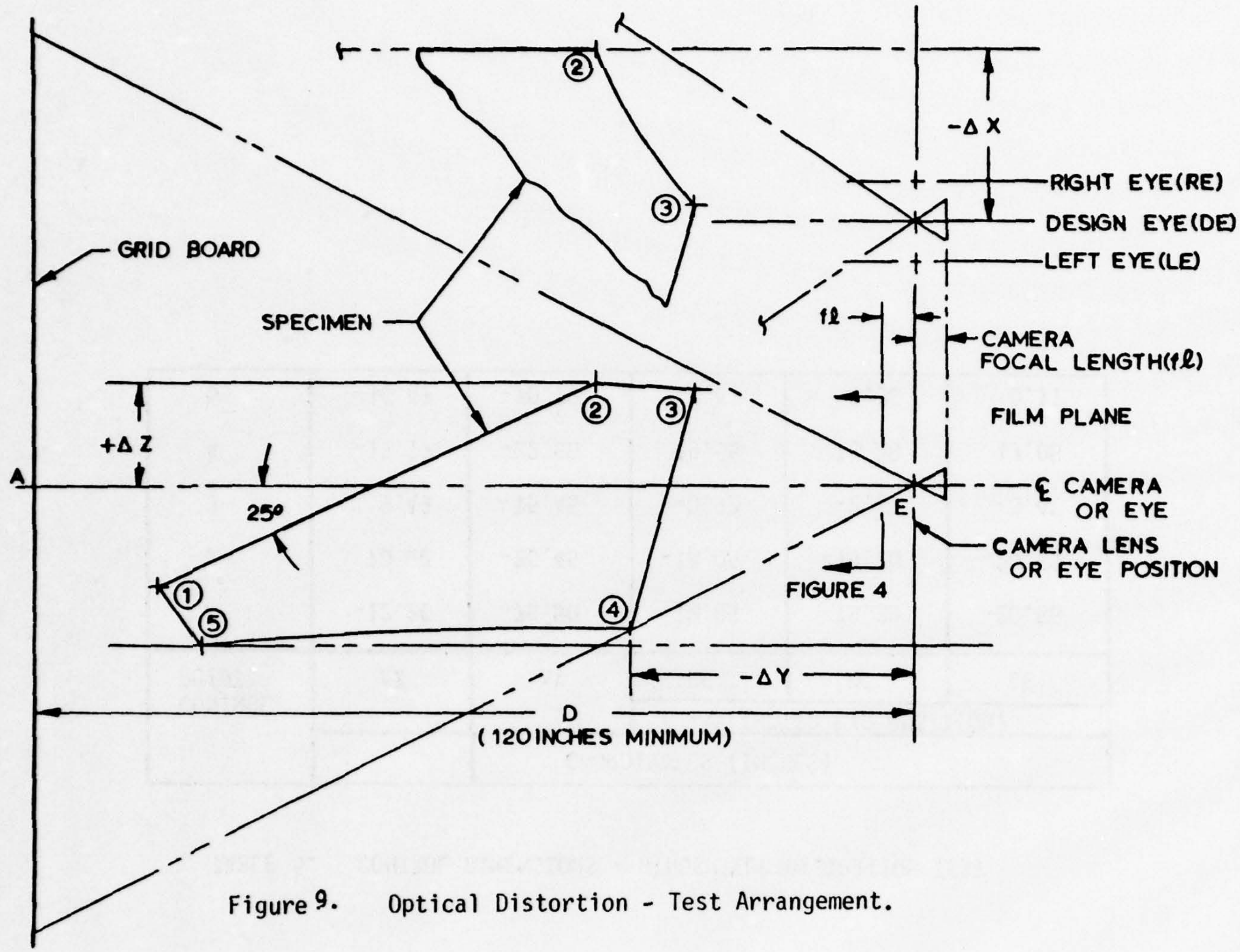


Figure 9. Optical Distortion - Test Arrangement.

TABLE 5. CONTROL DIMENSIONS - WINDSHIELD DISTORTION TEST

CONTROL POINT	COORDINATES (INCHES)				
			$-\Delta X$ (NOTED EYE POSITION)		
	ΔZ	ΔY	RE	DE	LE
1	-12.20	-75.50	-18.05	-19.30	-20.55
2	10.62	-26.45	-18.05	-19.30	-20.55
3	9.49	-15.45	-0.92	-2.17	-3.42
4	-17.17	-22.60	19.55	18.30	17.05
5	-18.67	-70.79	2.61	1.36	0.11

shall be established and approved by the procuring agency for visual comparison during the production phase of fabrication.

4.2.5 Weight. Each transparency, including edge retainers and stiffeners, shall be weighed on a calibrated balance. The weight shall be recorded to the nearest one tenth of a pound.

4.2.6 Precipitation Static.

4.2.6.1 Anti-Static Coating. The resistivity limits and uniformity specified in Section 3.2.1.5 shall be verified by measurement method and test probe defined by the supplier test method approved by the procuring agency.

4.2.6.2 Static Drain Path.

4.2.6.2.1 Anti-Static Drain Bus. The resistance of the anti-static drain bus shall be verified by resistance measurement. Sufficient measurements shall be performed to cover the entire bus and to assure continuity in the bus. Contact between the bus and anti-static coating shall be verified by resistive measurements between the bus and the resistive film immediately adjacent to the bus. An ohm meter using a probe employing a non-metallic conductor approximately 1/8 inch in diameter shall be used to make contact with the anti-static coating. The resistance between the drain bus and coating shall not exceed (TBD) ohms when the centerline of the probe is 1/8 inch from the inside edge of the bus for any location around the bus. The resistance between coating and drain bus shall not exceed the requirements of Section 3.2.1.5.2.1.

4.2.6.2.2 Static Drain Strap. The static drain strap design shall be verified by inspection for compliance with the drawing requirements. The bus to strap resistance shall be verified by tests. If a multi-segment strap is employed, resistance measurements shall be performed between the bus and each segment of the strap.

4.2.7 Anti-Ice System.

4.2.7.1 Anti-Ice System Acceptance Test. This test shall be performed in the following sequence:

Insulation Resistance
Dielectric Strength
Over-voltage
Bus-to-Bus Resistance
Temperature Sensing Elements
Coating Uniformity
Repeat Insulation Resistance

4.2.7.1.1 Insulation Resistance. The insulation resistance test shall be conducted by applying 500 Vdc potential for one minute. The resistance measured shall be not less than 75 megohms. The measurements shall be made between each two electrically insulated terminals and also jointly between the electrical terminals and the frame.

4.2.7.1.2 Dielectric Strength. The dielectric strength test shall be performed with 2500 volts RMS at commercial frequency. The test potential shall be applied at 500 volt increments. The dwell time at each increment shall be 30 seconds. The test potential shall be applied between all electrical terminals and the frame. The resultant current flow shall be less than one milliampere. Subsequent retests may be performed at 20 percent reduced potential, but not less than 1500 volts RMS.

4.2.7.1.3 Over-Voltage. The over-voltage test shall be performed at 150 percent of operating voltage and frequency. This voltage shall be applied for 30 ± 10 seconds.

4.2.7.1.4. Bus-to-Bus Resistance. The bus-to-bus (line-to-neutral) resistance for each heating segment shown in Figure 1 shall be 23.25 ± 10 percent ohms measured at room temperature.

4.2.7.1.5 Temperature Sensing Element. After lamination, each sensing element shall be tested by applying a potential of 10 $\pm$ 1 volt dc for a minimum of one minute. A current versus calculated resistance curve shall be plotted for each sensor. The resistance at any given current reading for any one of the sensors shall not deviate from the others by more than $\pm$ 1.0 percent.

4.2.7.1.6 Coating Uniformity. The coating shall be verified by measurement using the following methods.

4.2.7.1.6.1 Anti-Ice Coating. The anti-ice coating in areas A, B and C shall have the power density ratios verified by measurement using heat rate gauges, infrared systems, or an equivalent method. The manufacturer will stipulate the method he proposes to use subject to approval by the procuring agency.

4.2.7.1.6.2 Radar Cross Section . The resistive limits specified in Section 3.2.1.6 for areas D and E shall be verified using the measurement method and test probes defined by the supplier's test method approved by the procuring agency.

4.2.8 Electromagnetic Pulse Suppression. The requirements of Section 3.3.2.4.3 shall be verified as follows:

a. The internal sensor lead routing shall be inspected visually for minimum spacing of the leads.

b. The electrical path resistance between the eight EMP ground terminals and the windshield metal retainers shall be measured and shall not exceed 2.5 milliohms.

4.2.9 Inspection of Product. Inspection shall be performed on all production articles. Inspection shall consist, as a minimum, of the following: Quality of workmanship, material consistency, accuracy of dimensions, identification and markings. Inspection shall be performed prior to and at the conclusion of the acceptance test.

4.2.9.1 Check Fixtures. Check fixtures and equipment shall be provided for determining edge contour (free state and clamped), overall panel contour, edge trim thickness, hole alignment and hole size (including counterbores and countersinks).

4.2.9.2 Inspection. Using the check fixtures specified, each transparency shall be inspected for the dimensions and dimensional tolerances specified in Section 3.3.2 and shall be visually examined for general quality, workmanship and identification of product. Dimensional inspection shall be performed at a temperature of $75^{o} \pm 5^{o}F$. The hole and trim finish shall be mechanically (not visually) inspected before the bushings are inserted or the edge finish protective treatment is applied.

4.2.10 Materials Review Authority. Materials Review authority may be retained by the procuring agency or granted by the supplier in accordance with the provisions listed below.

4.2.10.1 Personnel. The supplier's Engineering and Quality Control personnel for Material Review action will be established by mutual agreement between the supplier and the procuring agency. Change in personnel shall require written notification to, and approval by, the procuring agency.

4.2.10.2 Limitations. Material Review authority vested in the supplier is expressly limited to the processing of variations which do not adversely affect fit, function, installation into next assembly, interchangeability, or service life.

4.2.10.3 Disposition. All discrepancies found during inspection of the transparencies shall be recorded on the supplier's material review record forms. Disposition shall be made internally in accordance with instructions contained in the supplier's quality control procedure. Disposition of the following conditions shall be as outlined below:

4.2.10.3.1 Deviations. End items with deviations in the following shall not be shipped without approval by the procuring agency.

a. Overweight transparencies.
b. Hole pattern (hole size excepted).
c. Optical angular deviation for those windshield panels which do not meet the critical area optical requirements.
d. Proof pressure.

4.2.10.3.2 Variations. End items with variations in the following shall be shipped only after proper approval of a cognizant procuring agency inspector.

a. Free state and clamped contour.
b. Optical characteristics -
    1. Distortion
    2. Angular Deviation
    3. Visual Optical
    4. Light transmittance and/or haze.

4.3 Reliability. At the conclusion of the series of bird impact, accelerated environmental and associated materials tests, the windshield manufacturer shall make an assessment of the data to verify that the requirements of Section 3.2.3 has been met. In the event that 3.2.3 has not been met, the manufacturer shall establish a service life based on his data for submittal to the procuring agency for approval.

5. PREPARATION FOR DELIVERY

5.1 Preservation and Packaging. The equipment shall be preserved and packaged in accordance with the supplier's best commercial practices.

5.2 Intermediate Packaging. The number of windshield panels shall not exceed one per container unless authorized by the procuring agency.

5.3 Packing. Shipments shall be packed in exterior type shipping containers in such a manner to ensure safe transportation at the lowest rate to a point of delivery. The construction of the shipping container shall be as follows.

5.3.1 Exterior. The exterior of the container shall be exterior cleated plywood, a minimum of 3/16 inch thick. All corners shall be reinforced with 1 x 2 inch batting and a minimum of two cross members shall be used on all six sides.

5.3.2 Outer Cushioning. The outer cushioning adjacent to the plywood shall be resilient expanded polystyrene, or equivalent, contoured as required to accommodate the part and inner cushion.

5.3.3 Inner Cushioning. The inner cushioning adjacent to the part shall be resilient polyurethane foam, or equivalent, contoured to make intimate contact with the part.

5.3.4 Steel Banding. A minimum of four steel bands, 1/2 inch x .020 high inch, shall be applied to the corners of the container.

5.4 Marking. All containers shall be marked in accordance with MIL-STD-130.

6. NOTES

6.1 Intended Use. The transparencies covered by this specification are intended for development for potential installation on B-1 aircraft.

6.2 Ordering Data.

6.2.1 Preproduction Specimens. Transparency - six (6) shipsets per Table 4.

6.2.2 Production. To be determined.

6.3 Definitions.

a. Penetration. Any portion of the chicken carcass, including fluids, which passes through the transparency or edge support structure into the crew compartment.

b. Critical Area. The area defined on the applicable drawing requiring the highest optical quality standards for forward vision.

c. Deviation. An angular change in the direction of a ray of light as it passes through a transparency with non-parallel surfaces, expressed in minutes of arc.

d. Distortion. Rate of change of deviation.

e. Grid Line Slope. The ratio of the rise to the run in terms of grid squares of a tangent at the maximum slope of a distorted grid line.

f. Lensing. Distortion which changes the apparent size of an object when viewed through the transparency as compared to the true perceived size of the object without the presence of the windshield.

g. Optical Defect. Surface damage, foreign matter inclusion, pits, seeds, and similar optical imperfections.

h. Bull's Eye. A type of distortion in which the grid lines converge or diverge about a point. This type is also known as barrel or pincushion distortion.

i. MTBF. Mean-Time-Between-Failure.

j. MMH/FH. Maintenance Man Hours per Flight Hours.

k. Test Plan. The words "test plan" as used within this specification, is the document that defines the suppliers' plan for accomplishing the tests required in Section 4. The following should be included as a minimum:

Facilities and Location
Test Equipment
Test Schedules
Test Specimen Drawings
Test Procedures - Section 4 requirements or deviations.
Quality Control Procedures.

l. Power Factors.

K_H = Ratio of power densities at the hot spot to control point

K_A = Ratio of the power density of the average power density to the control point.

K_M = Ratio of the average power density to the hot spot power density

K_C = Ratio of the cold spot power density to the control point power density.

6.4 Environmental Test Facility Description. The facility to provide the environment for the Accelerated Environmental Tests described in 4.1.2.2.1 should have the following characteristics:

a. Sufficient airflow to provide actual heat transfer coefficients that the transparency would encounter in flight.

b. Air source to pressurize the interior surface of the transparency.

c. Heating and cooling available to heat the exterior air to 290^{O}F and cool it to -80^{O}F.

d. Method to add moisture to the air to control the humidity.

e. Radiant heat source, including ultraviolet (possibly an Xenon or Hg-Xenon lamp with filters).

f. Water supply available to simulate rain impingement.

g. Conditioned air to represent the cockpit environmental conditions.

6.5 Hail Impact. Refer to AFFDL-TR-77-1, "Windshield Technology Demonstrator Program - Detail Design Options Study", dated December 1976. This report discusses the hailstone size and risks for various face ply thickness failures. Testing may be accomplished by ASTM Test Method ASTM-F320.

6.6 Static Drain Strap Minimum Requirements. Refer to AFFDL-TR-76-75, "Effects of Laboratory Simulated Precipitation Static Electricity and Swept Stroke Lightning on Aircraft Windshield Subsystems," dated July 1976.

6.7 Electromagnetic Isolation. Refer to AFFDL-TR-77-1, "Windshield Technology Demonstrator Program - Detail Design Options Study," dated December 1976. The windshield acts as a point of entry for Nuclear Electromagnetic Pulse (EMP) energy. The windshield anti-icing coating and associated electrical wiring forms the principle EMP signal entry into other subsystems within the aircraft. The following sections define the B-1 EMP interface requirements and the EMI provisions required in the windshield design and construction.

6.7.1 Temperature Sensor Elements. The sensor element EMI requirements are defined for the internal wiring (windshield side of the terminals) and the external wiring (aircraft side of terminals) as follows:

a. The internal leads from each sensor element to their respective terminals shall be routed as close together and along the shortest route that is practicable in order to minimize the electromagnetic loop area.

b. The external wiring for the sensor elements is presently proposed as follows:

1. Two leads, twisted, insulated and jacketed (shielded) from each sensor element pair of terminals.

2. The above leads from each heating area will be routed together and enclosed in a braided EMP shield. This external wire bundle will start at heating area "A" and terminate in a connector located approximately at the lower aft corner of heating area "C" (Ref. Figure 2).

3. The shield over each pair of sensor leads (Item 1 above) shall be grounded through individual pins within the connector (Item 2 above). This shield will not be grounded at the windshield terminals.

4. The EMP shield (Item 2 above) requires grounded terminals on the windshield assembly. An EMP terminal located near each group of four sensor terminals is required. An electrical path from each EMP terminal to the windshield metal retainers shall be required. The final aircraft grounding of the EMP terminals will be through the windshield attaching bolts. (Note: Except for these bolts, the windshield is insulated from the structure because of the two weather/pressure seals.) The EMP shield shall terminate peripherally on the external sensor wiring connector shell.

5. The receptacle body and backshell of the connector (Item 2) will be an "RFI" type with provisions for radio frequency bonding to the shell of the aircraft's interfacing connector.

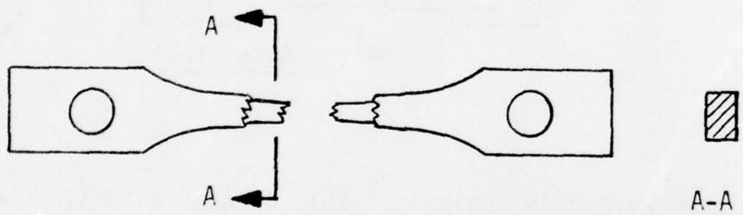
6.7.2 <u>Power and Neutral EMP Suppression</u>. The power terminal for each heating area and the two neutral terminals will require an EMP overvoltage suppressor device (Type TBD). The suppressor device at each of these terminals will require a ground terminal identical to Item 6.7.1.b.4. The external power and neutral wiring will be unshielded and routed parallel to the EMP shielded sensor external wiring and will terminate in a separate connector at approximately the same location noted in Item 6.7.1.b.2.

6.8 <u>Distortion Analysis</u>. The distortion analysis and testing defined in Appendix IV and called for in Section 4.2.4.5 is based on the method presented

in AFFDL-TR-77-1, "Windshield Technology Demonstrator Program - Detail Design Options Study", dated December 1976.

6.9 Core Ply Tests.

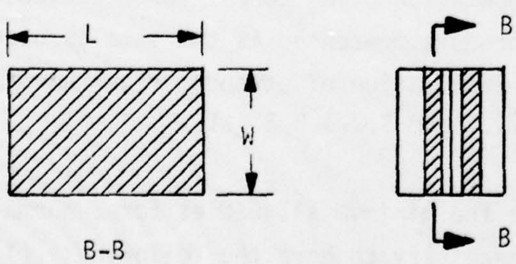
6.9.1 True Tensile Rupture Stress. The true rupture stress (σ_r) (reference Section 4.1.2.2.2) equals the rupture load (P_r) divided by the ruptured cross-sectional area (A_r) of the test specimen measured adjacent to the rupture point after removal of test load.



$$\sigma_r = \frac{P_r}{A_r} \text{ (psi)}$$

A-A Minimum Cross Section Area (A_r)

6.9.2 Rupture Shear Stress. The rupture shear stress (τ_r) equals the load at rupture (P_r) divided by the average interlayer shear area (A_o) of the test specimen measured prior to test.



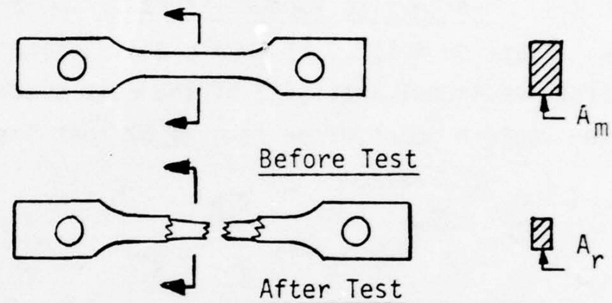
A_o Shear Area = W x L

$$\tau_r = \frac{P_r}{A_o}$$

6.9.3 True Tensile Rupture Strain . The rupture strain (ε_r) (reference Section 4.1.2.2.2) equals the natural log of the ratio of the specimen's initial minimum cross section area (A_m) divided by the specimen ruptured cross section area (A_r) measured at the rupture point of the specimen.

then:

$$\varepsilon_r = \mathrm{Ln}\,\frac{A_m}{A_r}$$



6.9.4 Strength Requirements Analysis. This procedure shall be used when a minimum acceptable mechanical property (σ_r, ε_r, τ_r) is to be computed directly from test results on the preproduction transparency and/or test panel that has successfully passed requirements of this specification. The specific transparency test specimens to be used in this analysis shall be from transparencies after testing per Section 4.1.2.2 using test results as specified in testing requirement Section 4.1.2.2.2.2. The material properties calculated represent the statistical minimums for the population using normal (or Gaussian) distributions. The computation procedure presented is the same as used in Report AFFDL-TR-77-96 for computation of strength requirements presented in Sections 3.2.1.3.3.1.1 and 3.2.1.3.3.2.1.

In order to compute the minimum allowables for a normally distributed population, it is necessary to have the following: (1) estimates of the mean ($\bar{X}$) and standard deviation(s) of the population and, (2) the one-sided tolerance limit factor (K). With test specimen population of small sample size N, mechanical properties of any specimen (X_i) available from 3.2.1.3.3, the computation of minimum strength properties is carried

out by use of the following formula

$$M = \overline{X} - K\,s$$

where

M = minimum guaranteed value (σ_r, ε_r, τ_r)

$$s = \sqrt{\Sigma(X_i - \overline{X})^2/N-1}$$

K = one-sided tolerance limit factor corresponding to a population of at least 90 percent of a normal distribution and a confidence coefficient of 95 percent. These values are as follows:

N	K
2	20.581
3	6.155
4	4.162
5	3.407
6	3.006
7	2.755
8	2.582
9	2.454
10	2.355

(Reference MIL-HNBK-5B, Table 9.6.4.)

6.9.4.1 Example Problem. The minimum tensile properties calculations for a specific processed polycarbonate material are as follows:

a. Calculate true rupture stress (σ_r) and true rupture strain (ε_r) from raw test data:

Specimen Number	A_m (IN^2)	P_r (LBS)	A_r (IN^2)	σ_r ($=P_r/A_r$) (psi)	ε_r ($=\text{Ln}\ \frac{A_m}{A_r}$)
1	.3680	2611	.2106	12,398	.558
2	.3740	2610	.2106	12,393	.574
3	.3721	2640	.2089	12,638	.577
4	.3724	2650	.2093	12,709	.576
5	.3701	2625	.2126	12,347	.554

b. Calculate the mean true rupture stress ($\overline{X}_\sigma$) and the mean true rupture strain ($\overline{X}_\varepsilon$) from test data as follows:

$$\overline{X}_\sigma = \frac{\Sigma\sigma_r}{N} = \frac{12398 + 12393 + 12638 + 12709 + 12347}{5} = 12497 \text{ psi}$$

$$\overline{X}_\varepsilon = \frac{\Sigma\varepsilon_r}{N} = \frac{.558 + .574 + .577 + .576 + .554}{5} = .568$$

c. Calculate the standard deviation for true rupture stress (s_σ) and for true rupture strain (s_ε) as follows:

$$s_\sigma = \sqrt{\Sigma(\sigma_r - \overline{X}_\sigma)^2/N - 1}$$

$$\sqrt{\frac{(12398 - 12497)^2 + (12393 - 12497)^2 + (12638 - 12497)^2}{5-1} \frac{+ (12709 - 12497)^2 + (12347 - 12497)^2}{5-1}} = 164.49$$

$$s_\varepsilon = \sqrt{\Sigma(\varepsilon_r - \overline{X}_\varepsilon)^2/N-1}$$

$$= \sqrt{\frac{(.588 - .568)^2 + (.574 - .568)^2 + (.577 - .568)^2}{5-1} \frac{+ (.576 - .568)^2 + (.554 - .568)^2}{5-1}} = .0109$$

d. Calculate the minimum guaranteed rupture stress [$M(\sigma_r)$ or $\overline{\sigma}_r$] and minimum guaranteed rupture strain [$M(\varepsilon_r)$ or $\overline{\varepsilon}_r$].

From Section 6.9.4, $K = 3.407$ for $N = 5$

$$\overline{\sigma}_r = \overline{X}_\sigma - K\, s_\sigma = 12.497 - 3.407\ (164.49) = 11,936 \text{ psi}$$

$$\overline{\varepsilon}_r = \overline{X}_\varepsilon - K\, s_\varepsilon = .568 - 3.407\ (.0109) = .531$$

6.9.5 Process Comparison Tests. The "F"-test and "T"-test provide means of comparing the variances (s^2) and means ($\overline{X}$) of two test samples of unpaired data, to test the hypothesis that the processed test panel represents the production transparency to meet requirements of 4.1.2.2. The variance is the square of the standard deviation.

6.9.5.1 "F"-Test. The "F"-test provides a method for determining whether the ratio of two variances is larger than might be expected by chance if they were from the same parent population. The null hypothesis is that the variances of the two samples are equal. The calculation of "F" is as follows:

$$F = \frac{s^2(X_2)}{s^2(X_1)}$$

where $s^2(X_2)$ = the larger variance of the samples,

$s^2(X_1)$ = the smaller variance of the samples.

To determine whether the two variances are from the same population, calculate "F" per above equation, then look up a value for "F" in Table 6, using N_1-1 and N_2-1 degrees of freedom. If the calculated "F" is larger than the value from Table 6, reject the hypothesis, with less than 1 chance in 100 of being wrong (99% confidence). If the calculated "F" is smaller than the value from Table 6 look up "F" in Table 7 and compare. If the calculated "F" is larger than the value from Table 7, reject the hypothesis with less than 1 chance in 20 of being wrong (95% confidence). If the calculated "F" is smaller than the value from Table 7, accept the hypothesis that the test panel represents the transparency.

TABLE 6. "F" DISTRIBUTION - 99% CONFIDENCE - 2 TAIL

N_2-1 → / N_1-1 ↓	1	2	3	4	5	6	7	8	9	10
1	16,200	20,000	21,600	22,500	23,100	23,400	23,700	23,900	24,100	24,200
2	199	199	199	199	199	199	199	199	199	199
3	55.6	49.8	47.5	46.2	45.4	44.8	44.4	44.1	43.9	43.7
4	31.3	26.3	24.3	23.2	22.5	22.0	21.6	21.4	21.1	21.0
5	22.8	18.3	16.5	15.6	14.9	14.5	14.2	14.0	13.8	13.6
6	18.6	14.5	12.9	12.0	11.5	11.1	10.8	10.6	10.4	10.2
7	16.2	12.4	10.9	10.1	9.52	9.16	8.89	8.68	8.51	8.38
8	14.7	11.0	9.60	8.81	8.30	7.95	7.69	7.50	7.34	7.21
9	13.6	10.1	8.72	7.96	7.47	7.13	6.88	6.69	6.54	6.42
10	12.8	9.43	8.08	7.34	6.87	6.54	6.30	6.12	5.97	5.85

N_2-1 = Numerator

N_1-1 = Denominator

TABLE 7. "F" DISTRIBUTION - 95% CONFIDENCE - 2 TAIL

N_2-1 → / N_1-1 ↓	1	2	3	4	5	6	7	8	9	10
1	648	800	864	900	922	937	948	957	963	969
2	38.5	39.0	39.2	39.2	39.3	39.3	39.4	39.4	39.4	39.4
3	17.4	16.0	15.4	15.1	13.9	14.7	14.6	14.5	14.5	14.4
4	12.2	10.6	9.98	9.60	9.36	9.20	9.07	8.98	8.90	8.84
5	10.0	8.43	7.76	7.39	7.15	6.98	6.85	6.76	6.68	6.62
6	8.81	7.26	6.60	6.23	5.99	5.82	5.70	5.60	5.52	5.46
7	8.07	6.54	5.89	5.52	5.29	5.12	4.99	4.90	4.82	4.76
8	7.57	6.06	5.42	5.05	4.82	4.65	4.53	4.43	4.36	4.30
9	7.21	5.71	5.08	4.72	4.48	4.32	4.20	4.10	4.03	3.96
10	6.94	5.46	4.83	4.47	4.24	4.07	3.95	3.85	3.78	3.72

N_2-1 = Numerator

N_1-1 = Denominator

6.9.5.2 "T"-Test. The "T" -test provides a method for determining whether two samples could have come from the same populations with the same (but unknown) mean. It is assumed for this test that the two populations have the same standard deviation. The null hypothesis is that the two population means are equal and the calculation for "T" is:

$$T = \frac{\overline{X}_1 - \overline{X}_2}{\overline{s}(X)\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where: $\overline{X}_1$ and $\overline{X}_2$ = respective sample means

N_1 and N_2 = respective numbers of data points in each of the two samples.

and the pooled standard deviation $\overline{s}(X)$ is:

$$\overline{s}(X) = \sqrt{\frac{(N_1-1)s^2(X_1) + (N_2-1)s^2(X_2)}{N_1 + N_2 - 2}}$$

where: $s^2(X_1)$ and $s^2(X_2)$ = respective sample variances.

To determine whether the two sample means are significantly different, we plot "T" at $N_1 + N_2 - 2$ on Figure 10 and note its position with respect to curves A and B. If "T" fails below curves A and B, accept the hypothesis that the means are from the same population. If "T" falls between curves A and B we reject the hypothesis that the sample means come from the same population with less than one chance in 20 of this conclusion being in error. If "T" falls above curves A and B we reject the hypothesis that the two sample means come from the same population with less than 1 chance in 100 of error.

6.9.5.3 Example Problem. The tensile data used in the previous example 6.9.5.1 (Case 1) are compared with unpaired data (Case 2) from a different lot (batch) of Lexan polycarbonate. Comparison of these two materials is made as described in 6.9.5.1 and 6.9.5.2.

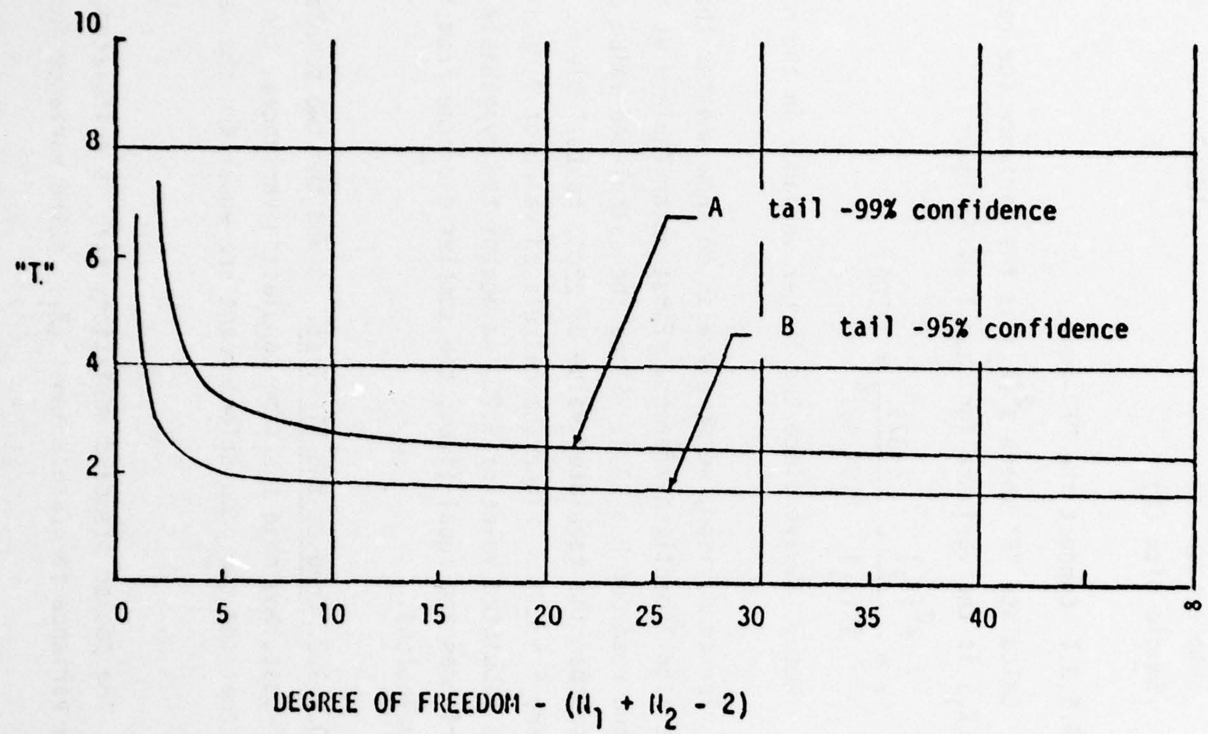


Figure 10. "T" distribution values.

	Case 1	Case 2
Sample standard deviation (s(X))	164.49	437
Sample mean ($\overline{X}$)	12497	12,452
Sample size (N)	5	7

6.9.5.3.1 Conduct the "F"-test.

a. Calculate "F" where $s^2(X_2)$ is the variance for case 2 example and $s^2(X_1)$ is the variance for case 1 as follows:

$$F = \frac{s^2(X_2)}{s^2(X_1)} = \frac{(437)^2}{(164.49)^2} = 7.06$$

Note: Always place the larger variance in the numerator.

b. For comparison, we merely wish to know whether the two variances are significantly different. First enter Table 6 at N_1-1 = 4 and N_2-1 = 4 and read out F = 22.0. Since the calculated value of F = 7.06 is less than the tabulated value of 22.0, go to Table 7. Again obtain F, where F = 9.20 . Since the calculated value of 7.06 is less than the tabulated value of 9.20, we accept the hypothesis that the two variances are equal (i.e., the samples did come from the same population).

6.9.5.3.2 Conduct the "T"-Test. Since the two populations passed the "F"-test, and have the same population variances, the null hypothesis is that the two populations means are equal and the calculation for "T" is:

a. The pooled standard deviation, $\overline{s}(X)$ is calculated, where $s^2(X_2)$ is the variance for Case 2 and $s^2(X_1)$ is the variance for Case 1, as follows:

$$\bar{s}(X) = \sqrt{\frac{(N_1-1)s^2(X_1) + (N_2-1)s^2(X_2)}{N_1 + N_2 - 2}}$$

$$= \sqrt{\frac{(4)\ (164.49)^2 + (6)\ \ (437)^2}{(5 + 7) - 2}} = 354.12$$

b. Calculate "T" where $\bar{X}_1$ is the sample 1 mean and $\bar{X}_2$ is the sample 2 mean, as follows:

$$T = \frac{\bar{X}_1 - \bar{X}_2}{\bar{s}(X)\ \sqrt{\frac{1}{N_1} + \frac{1}{N_2}}}$$

$$= \frac{12497 - 12,482}{354.12\ \sqrt{\frac{1}{5} + \frac{1}{7}}} = 0.07$$

c. For comparison, enter Figure 10 and compare with Cases A and B. Since the plot is below both curves, we can accept the hypothesis that the two sample means come from the same population.

APPENDIX I

10. BIRD IMPACT QUALIFICATION TEST PLAN

10.1 Test Objectives. The purpose of this qualification test is to demonstrate the structural capability of the manufacturer's windshield. The transparencies shall withstand, without penetration or pilot incapacitation, at a critical location, the impact of bird as required in section 3.2.1.1.

10.2 Test Facility. Testing shall be accomplished at a facility selected and approved by the procuring agency. The test facility shall furnish test engineers, technicians, cameramen, and personnel capable of installing and removing the test article and shall have the capability of meeting the requirements stated in 10.5.

10.3 Test Article. The windshield configuration to be tested, either Z5943224 or Z5943245, as defined in section 3.1, shall be selected by the manufacturer and procuring agency, dependent upon the manufacturer's manufacturing methods, processes and capabilities.

10.4 Test Description. This test plan requires that testing of five windshields of the configuration selected by the manufacturer/procuring agency be accomplished. Each windshield shall be impacted under the environmental parameters shown in Table 8 by a four (4) pound bird traveling at the noted velocity. The first three bird impact tests will be on windshields that have not been subjected to any environmental testing. The fourth and fifth tests will be at 195^{o} temperature or windshields that were previously subjected to two lifetimes of accelerated environmental testing per Section 20. The windshields will be instrumented with thermocouples and will be installed in an appropriate windshield support structure. A simulated glareshield shall be installed to determine whether or not the windshield deflection exceeds established limits. Damage to a windshield will be evaluated for potential pilot incapacitation.

10.5 Test Conditions.

10.5.1 Support Structure. The windshields to be tested shall be installed in the crew module. The module must be modified to accept the electrical/avionic system.

10.5.2 Bird Weight and Packaging. Test birds shall be either freshly killed or quickly frozen after killing and slowly thawed for 24 hours prior to testing. Each test bird shall consist of a complete carcass weighing 4.0 to 4.2 pounds. Weight adjustments may be made by clipping carcass appendages or by injecting water into the body cavity. The bird shall be packaged in accordance with methods approved by the procuring agency and monitored with high speed cameras (5,000 frames per second) to verify that the package is intact at impact.

10.5.3 Bird Velocity. The bird velocity shall be 565 ± 2.5 percent knots. The bird velocity shall be measured with an X-ray measurement or equivalent system.

10.5.4 Target Point. The target points shall be as shown in Figure 11. The tolerance for locating the target point shall not exceed ±0.12 inch.

10.5.5 Impact Point. The impact point tolerance shall not exceed ±1.00 inch from the selected target point and shall be verified with high speed cameras (5,000 frames per second).

10.5.6 Temperature Requirements. The surface temperatures for the cold birdstrike shall be -60°F outside and ambient inside. The surface temperatures for the hot birdstrikes shall be 230°F outside and ambient inside. The temperature tolerance shall not exceed ±10°F. An enclosure shall be mounted around the transparency to permit temperature control. Insulated ducting will be required as well as heating and cooling material.

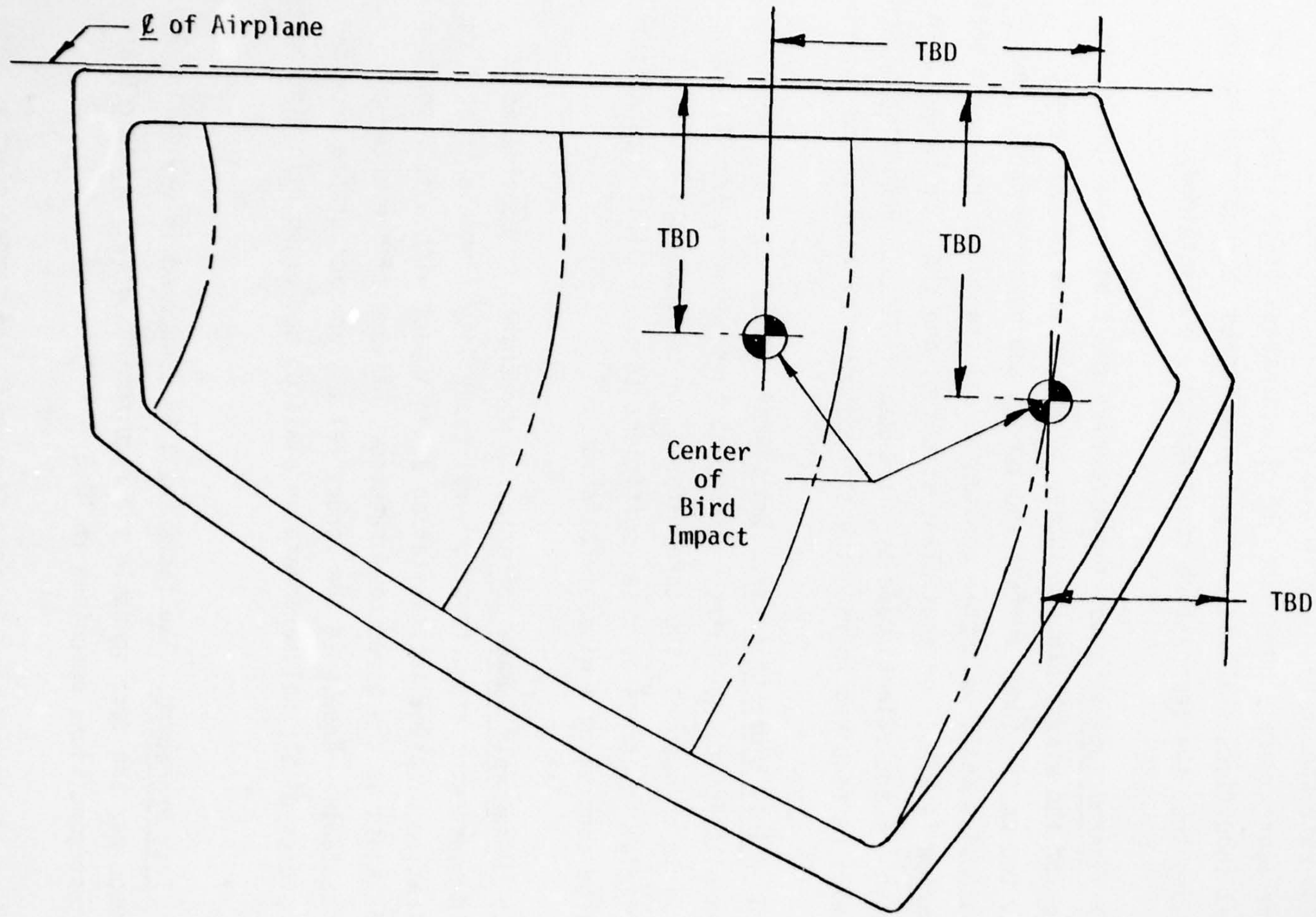


Figure 11. Location of Target Points.

AD-A080 129 DOUGLAS AIRCRAFT CO LONG BEACH CA F/G 1/3
STANDARDIZED WINDSHIELD FABRICATION SPECIFICATION.(U)
NOV 77 R I BECK, L P KOESEBOEHN, J H LAWRENCE F33615-75-C-3105
UNCLASSIFIED MDC-J7178 AFFDL-TR-77-97 NL

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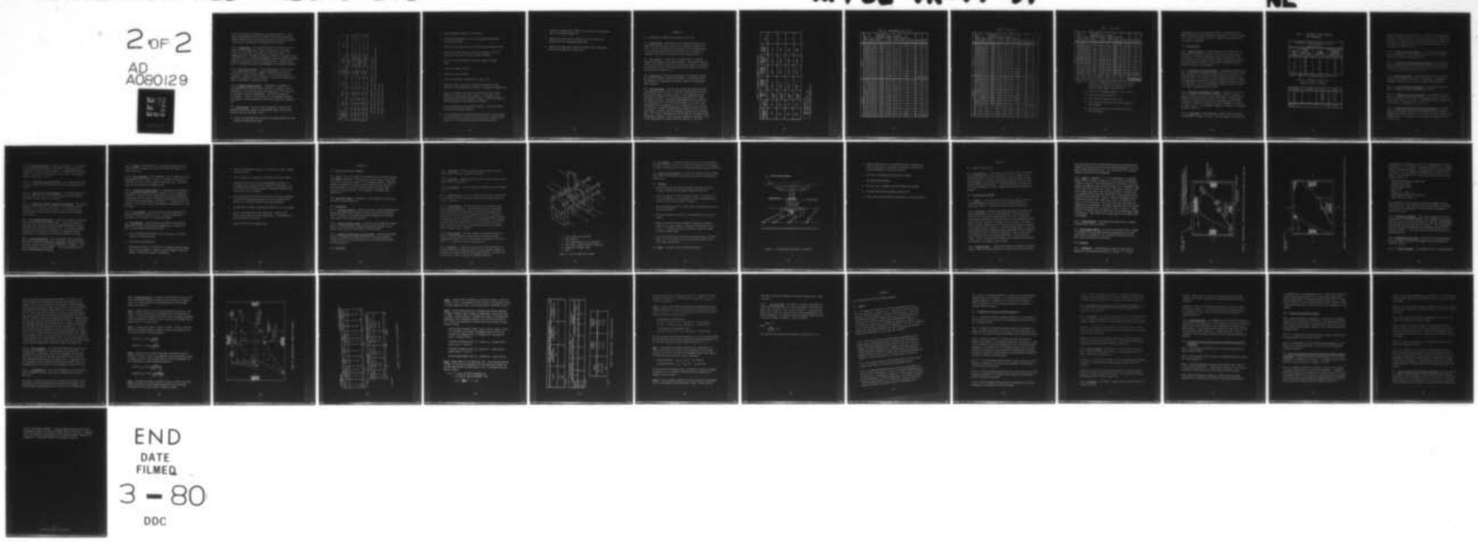

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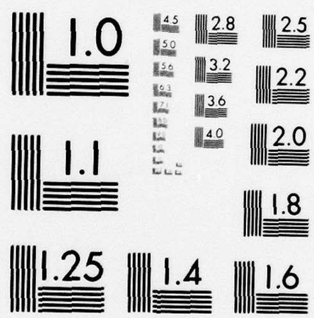


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

The flow rate should be approximately one pound per second. It will require approximately 30 minutes to obtain steady state temperatures. Thermal conditions shall be constantly monitored on recording equipment to ensure that the temperature requirements are maintained.

10.5.7 Thermocouples. Four thermocouples shall be installed on the surface of the windshield six inches on either side of the target point, two on the inner surface and two on the outer surface. The thermocouples shall be copper constantan calibrated to Instrument Society of America (I.S.A.), or equivalent standard, and shall be bonded with GA-2 adhesive (or equivalent) made by Micro-Measurements. Recording equipment will be required to read the thermocouples at half-second intervals.

10.5.8 Pilot Injury Criteria. Two styrofoam dummies shall be located in the pilot/co-pilot chairs. Damage to these dummies from flying windshield or support structure material or bird carcass excessive of superficial scratches or cuts, sufficient to cause pilot incapacitation, shall be considered a windshield failure.

10.5.9 Windshield Damage Criteria. A windshield is considered to have demonstrated adequate structural capability if there is no bird penetration or pilot incapacitation after impact with a four pound bird at 565 knots at the given temperatures. Failure of the outer ply is acceptable. Cracks in the structural ply are acceptable provided that pieces of the polycarbonate or glass do not cause pilot incapacitation.

10.6 Test Procedure. The tests shall be conducted in the following sequence per the test schedule and requirements given in Table 8 and the test conditions described in 10.5.

a. Install the crew module test fixture to the target platform with the forward end facing the bird gun.

TABLE 8. BIRD IMPACT TEST SCHEDULE

WINDSHIELD (SYSTEM) NUMBER	TEST NUMBER	VELOCITY (KNOTS)	BIRD WEIGHT (LBS.)	SURFACE TEMP. EXTERIOR/ INTERIOR	IMPACT LOCATION	NOTES
T 01	B01	565	4	-60/1	CENTER OF W/S	4
T 02	B02	565	4	230/5	AFT CORNER	
T 03	B03	565	4	AMBIENT	CTR. BEAM	
T 04	B04	565	4	-60/1	CENTER OF W/S	1 , 2 , 3
T 05	B05	565	4	230/1	AFT CORNER	4 , 2

1 INTERIOR SURFACE TEMPERATURES 75^{0} (AMBIENT) $\pm 5^{0}$ (COCKPIT SIDE).

2 TO BE COMPLETED AFTER TWO LIFETIMES OF CYCLIC PRESSURE/TEMPERATURE TESTING.

3 THE ANTI-ICING SYSTEM SHALL BE ON.

4 THE ANTI-ICING SYSTEM SHALL BE OFF.

b. Install windshield Number T01 for testing.

c. Attach the thermocouple wiring to the windshield and recorder; calibrate the system.

d. Install the styrofoam dummies in the pilot and co-pilot positions.

e. Set up a high speed camera to verify the integrity of the bird package at impact and to verify the impact location.

f. Position the gun and support structure to impact the target point.

g. Install the thermal enclosure.

h. Prepare the gun for firing.

i. Stabilize the external temperatures at $-60^{o}F \pm 10^{o}$.

j. Remove the thermal enclosure and impact the windshield target point with a four-pound bird at 565 knots to complete test Number B01.

k. Check the windshield for damage and record the results. Record whether or not the dummies were injured. If the windshield is penetrated, measure the windshield thickness. Remove the windshield from the structure if the windshield is damaged.

l. Record temperatures, bird weight and velocity. Verify bird impact point and bird package integrity.

m. If the windshield has withstood the birdstrike event without penetration or pilot injury as noted in 10.5.8 and 10.5.9, proceed to the next test. Five birdstrikes complete the required testing.

n. Complete test Number B02 at 230°F $\pm$ 10° as noted in 10.6.b through 10.6.m for windshield Number T02.

o. Complete test Number B03 at ambient (75° $\pm$ 5°) per steps 10.6 through 10.6.m for transparency Number T03.

p. Complete test Number E01 on windshield Number T04 per Section 20. Perform test Number B04 at -60°F $\pm$ 10°.

APPENDIX II

20. ACCELERATED ENVIRONMENTAL QUALIFICATION TEST PLAN

20.1 Test Objective. The purpose of this qualification test is to demonstrate the structural capability of a laminated windshield for the B-1 aircraft by subjecting the windshield to proof pressure tests, cyclic pressure, temperature and ultraviolet tests, including rain impingement, humidity and operational ultimate pressure tests.

20.2 Test Facility. Testing shall be accomplished at a facility selected and approved by the procuring agency. The test facility shall furnish test engineers, technicians and personnel capable of installing and removing the test article and shall have the capability of meeting the requirements stated in 20.5.

20.3 Test Article. The two configurations to be potentially tested are defined on drawings Z5943224 and Z5943245. The configuration to be tested shall be selected by the vendor, subject to the procuring agency approval.

20.4 Test Description. This test plan requires the testing of three transparencies and four tests for the design configuration selected by the procuring agency as shown in Table 9. Each transparency to be tested will be installed in the crew module and tested in a flight environment simulator. Appropriate instrumentation will be installed. Each transparency will be proof pressure tested to 14.1 PSIG. Each transparency will be subjected to a cyclic pressure of 0 to 10.6 PSIG (1P condition), external air temperatures ranging from -65°F to 276°F, intermittent ultraviolet radiation exposure, humidity and rain impingement. The first two transparencies (T04 and T05) will be tested to two transparency lifetimes of 1000 cycles per lifetime as described in Table 10 and subsequently bird impact tested per Section 10. The third

TABLE 9. ACCELERATED ENVIRONMENTAL TEST SCHEDULE

TRANSPARENCY NUMBER	TEST NUMBER	NUMBER OF CYCLES	INTERNAL PRESSURE (PSIG $^{+.2}_{-0}$)	EXTERNAL AIR TEMP (°F $\pm$10°)	TIME AT PRESSURE (MVM)	U.V. EXPOSURE HOURS	NOTES
T04	E01	2 LIFE-TIMES	TABLE 11	TABLE 11	TABLE 11	600	B
T05	E02	2 LIFE-TIMES	TABLE 11	TABLE 11	TABLE 11	600	B
T06	E03	1 LIFE-TIME	TABLE 11	TABLE 11	TABLE 11	600	A
T06	E04	4 LIFE-TIMES	TABLE 11	TABLE 11	TABLE 11	1200	C

A PROOF PRESSURE TEST

B BIRD IMPACT TEST (SECT. 10)

C OPERATIONAL ULTIMATE PRESSURE TEST

TABLE 10. ENVIRONMENTAL CYCLIC TESTS

	EXT. AIR TEMP. (°F)	INT. PRESS. (PSI)	EXT. HEAT TRANSFER COEFFICIENT (BTU/HR-FT^2-°F)	CUMULATIVE TIME (MIN.)	TIME @ TEMP/PRESS. (MIN.)	RADIANT HEAT (NOTES)	HUMIDITY (LB/LB)	CYCLES REQ'D	HOURS REQ'D
PHASE I	-23	0	25/2	0		(1)			
	-23	10.6	25/2	1	1				
	240	10.6	40/2	11	10				
	268	10.6	37/2	15	4				
	264	10.6	29/2	25	10				
	234	10.6	27/2	27	2				
	-55	10.6	25/2	33	6				
	-45	10.6	25/2	45	12				
	57	10.6	75/2	50	5				
	57	-4.4	75/2	51	1				
	57	-4.4	75/2	55	4				
	-31	10.6	21/2	60	5	(2)			
	-31	10.6	20/2	65	5	(2)		200	216.7
PHASE II	59	0	10/2	0					
	87	10.6	47/2	1	1				
	0	10.6	25/2	6	5				
	0	10.6	25/2	11	5				
	240	10.6	40/2	17	6				
	270	10.6	37/2	18	1				
	270	10.6	29/2	28	10				
	240	10.6	27/2	29	1				
	-34	10.6	25/2	34	5				
	-21	10.6	25/2	44	10				
	143	10.6	75/2	49	5				
	143	-4.4	75/2	54	5				
	-48	-4.4	21/2	60	6	(2)			
	-48	-4.4	21/2	65	5	(2)		500	541.6

TABLE 10. (Continued)

	EXT. AIR TEMP. (°F)	INT. PRESS. (PSI)	EXT. HEAT TRANSFER COEFFICIENT (BTU/ HR-FT^2-°F)	CUMULATIVE TIME (MIN.)	TIME @ TEMP/ PRESS. (MIN.)	RADIANT HEAT (NOTES)	HUMIDITY (LB/LB)	CYCLES REQ'D	HOURS REQ'D
PHASE III	-65	0	10/2	0					
	-56	10.6	25/2	1	1				
	-56	10.6	25/2	6	5				
	186	10.6	40/2	12	6				
	210	10.6	37/2	13	1				
	173	10.6	29/2	23	10				
	-65	10.6	25/2	29	6				
	-65	10.6	25/2	41	12				
	-36	10.6	75/2	46	5				
	-36	-4.4	75/2	41	5	(2)			
	-65	-4.4	20/2	46	5	(2)			
	-65	10.6	20/2	51	5	(2)		50	42.5
PHASE IV	65	0	10/2	0					
	276	10.6	42/2	5	5				
	273	10.6	26/2	16	11				
	17	10.6	25/2	21	5				
	17	10.6	25/2	31	10				
	234	-4.4	75/2	36	5				
	234	-4.4	75/2	45	9				
	-1	10.6	21/2	50	5	(3)			
	-1	10.6	20/2	57	7	(3)			
	120	10.6	10/2	61	4				
	120	10.6	10/2	66	5			100	110

TABLE 10. (Continued)

	EXT. AIR TEMP. (°F)	INT. PRESS. (PSI)	EXT. HEAT TRANSFER COEFFICIENT (BTU/HR-FT^2-°F)	CUMULATIVE TIME (MIN.)	TIME @ TEMP/PRESS. (MIN.)	RADIANT HEAT (NOTES)	HUMIDITY (LB/LB)	CYCLES REQ'D	HOURS REQ'D
PHASE V	90	0	10	0		360 (4)	.016		
	120	10.6	47	1	1	360	.016		
	24	10.6	25	4	3	430	Low		
	24	10.6	25	9	5	430	Low		
	240	10.6	40	15	6	430	Low		
	245	10.6	37	16	1	430 (6)	Low		
	206	10.6	29	28	12	430	Low		
	179	10.6	25	29	1	430	Low		
	-17	10.6	25	35	6	430 (3)	Low		
	-17	10.6	25	45	10	430 (3)	Low		
	200	-4.4	75	50	5	360 (5)	.016		
	200	-4.4	75	60	10	360 (5)	.016	200	200
								1000	1110.8

NOTES:
(1) Internal air temperature shall be 75° ± 5°F for all phases and the internal heat transfer coefficient should be approximately 2 BTU/HR-FT^2-°F.

(2) Anti-ice off (standard operation is anti-ice on).

(3) Anti-ice off every 10th cycle.

(4) Every 10th cycle humidity 0.028 lb/lb.

(5) Every 10th cycle ram and jet blast rain removal on for 5 minutes.

(6) Every 20th cycle rain fall at rate of 0.06 in/hr. for five minutes.

transparency (T06) will be cycled 4000 times to simulate four transparency lifetimes and then subjected to an operational ultimate pressure of 21.5 PSIG as specified in Table 11. Damage to any windshield will be evaluated and reported.

20.5 Test Conditions

20.5.1 Support Structure. The transparencies to be tested shall be installed in a modified crew module. Modifications to the support structure shall have been accomplished prior to these tests. These modifications will make the structure capable of withstanding the pressure and temperature conditions and compatible interfacing with the electronic systems in the windshield.

20.5.2 Simulation of Flight Environment. A transparency flight environment simulator shall be designed and fabricated at the direction of the procuring agency or an existing simulator be acquired subject to the procuring agency. The simulator shall be designed and built to satisfy the temperature, pressure, heat transfer, ultraviolet exposure, humidity, rain impingement, and cyclic requirements defined in Tables 9, 10 and 11 in order to complete the test program.

20.5.3 Definition of Transparency Lifetime. The usage for a B-1 aircraft is defined in AFFDL-TR-77-1, WTDP-Design Options, and results in 5000 total flight hours and 15 total service years. One transparency lifetime is defined as 6000 hours and is equivalent to 1000 cycles. The number of lifetimes to be applied to each transparency is defined in Tables 9 and 10. A transparency lifetime is divided into five phases as shown in Table 10.

20.5.4 Test Duration. One transparency lifetime of testing consists of 1000 cycles as noted in Table 10. The time required to complete one

TABLE 11. OPERATIONAL ULTIMATE PRESSURE TEST REQUIREMENTS

CONDITIONS: 10 Minute Supersonic Cruise MACH 1.8 at 4°F			
CUMULATIVE TIME (MINUTES)	EXTERNAL AIR TEMPERATURE (°F ± 10°)**	INTERNAL PRESSURE (PSIG + 0.2-0)	EXTERNAL HEAT TRANSFER COEFFICIENTS (BTU/HR-FT^2-F°)
0	160	0	4
1.7	290	14.1	50
11.1	290	14.1	50
11.2	290	21.1	50
11.7	290	21.1	50
13.3	120	0	4

**NOTE: Internal Air Temperature Shall be 75°F ± 5°.

TABLE 12. DURATION OF CYCLIC TESTS (BASED ON 1 WEEK = 120 HOURS)

TEST NUMBER	LIFETIMES	CYCLES	WEEKS
E01	2	2000	18.5
E02	2	2000	18.5
E03	4	4000	37.0
E04	-	-	-
TOTAL			74.0

lifetime of testing is 1110 hours. This is equivalent to approximately 9.25 weeks at 5 days per week, 24 hours per day. The total times, shown in Table 12, to complete the accelerated environmental test schedule is 74.0 weeks and is based on the use of one modified crew module, and one flight environment simulator.

20.5.4.1 Proof Pressure Test Duration. The proof pressure test shall be one cycle applied to every transparency and will be of 15 minutes duration as specified in Tables 9 and 10.

20.5.4.2 Operational Ultimate Pressure Test Duration. The operational ultimate pressure test shall be one cycle applied to one transparency (T06) at the completion of four lifetimes of testing and shall be of 13.3 minutes duration as specified in Table 11.

20.5.5 *Thermal Requirements.* Temperature sensors shall be installed to monitor the external and internal air temperature. Programmable temperature controllers will be used to control the temperatures.

20.5.5.1 Proof Pressure Test Requirements. The proof pressure tests shall be conducted at ambient temperature per Table 9.

20.5.5.2 Lifetime Cyclic Test Requirements. The lifetime cyclic tests shall be conducted at the external air temperatures given in Table 10 and will vary from -65°F to 276°F. The tolerances shall not exceed ±10°F. The internal air temperature will be 75° ± 5°F.

20.5.5.3 Operational Ultimate Pressure Test Requirements. The operational ultimate pressure tests shall be conducted at the external air temperature specified in Table 11 and will vary from 120°F to 290°F. The tolerances shall not exceed ±10°F. The internal air temperatures will be 75°F ± 5°F.

20.5.6 Pressure Requirements. Pressure transducers will be installed to verify the internal pressure requirements. Safety dumps will be installed to prevent over-pressurization. A programmable pressure controller will be used to control pressurization rates. The tolerance shall not exceed +0.2, -0 PSIG.

20.5.6.1 Proof Pressure Test Requirements. The internal pressure for this test shall be 14.1 PSIG as shown in Table 9 and defined as 1.33 times 1P.

20.5.6.2 Lifetime Cyclic Test Requirements. The internal pressure for this test shall vary from 0 to 10.6 PSIG for each of five phases as specified in Table 10 and is a 1P condition.

20.5.6.3 Operational Ultimate Pressure Test Requirements. The internal pressure for this test shall vary from 0 to 14.1 PSIG (2/3 maximum pressure) to 21.1 PSIG as shown in Table 11, and is defined as the maximum internal pressure plus external pressure plus port reference error pressure.

20.5.7 Heat Transfer Requirements. External heat transfer coefficients are given in Table 10 for the cyclic tests. These heat transfer coefficients were calculated for the five flight environments listed in Table 10 and vary from 10 to 75 BTU/HR-FT^2-°F. The flight environment simulator shall be designed to achieve similar test heat transfer coefficients by varying the airflow over the surface of the canopy.

20.5.8 Ultraviolet Radiation. Each transparency shall be exposed to 600 hours of ultraviolet exposure per transparency lifetime of testing, as shown in Table 9 per MIL-STD-810C, METHOD 505.1, Procedure 1. The rate of exposure will be approximately 50 hours per 100-120 hours of cyclic pressure/temperature testing.

20.5.9 Humidity. Ambient humidity is acceptable except the humidity shall be 0.016 to 0.028-lb/lb. of dry air at 120°F for Phase V, as shown in Table 10.

20.5.10 Rain Impingement. Each transparency shall be subjected to rain impingement as part of Phase V, Table 10. The rate of flow shall be 0.060-inch per hour for five minutes of every 20th cycle. The flow of water shall be directed from forward to aft.

20.5.11 Transparency Damage Criteria. A transparency is considered to have demonstrated adequate structural capability if it withstands two transparency lifetimes of cyclic testing without damage, delamination or edge separation and meets all the optical requirements of Section 30 and the bird impact requirements of Section 10. A transparency will be inspected after each static test and periodically during the cyclic tests for damage.

20.5.12 Test Completion. The test facility shall be responsible for completing the tests as detailed in 20.6. The test series may be terminated at the discretion of the procuring agency.

20.6 Test Procedure. The tests shall be conducted in the following sequence per the test schedule and requirements given in Table 9, 10 and 11, and the conditions described in 20.5.

a. Install windshield T04 and T06 to the crew module in the flight simulator to commence testing.

b. Calibrate the instrumentation.

c. Pressurize the system to 10.6 PSIG for 15 minutes at ambient temperature to test for seating. Check for possible damage to the transparency. Evaluate and proceed if acceptable.

d. Turn on the crew module cooling air to maintain an internal temperature of 75 $\pm$ 5°F.

e. Cool the external air supply to -23° $\pm$ 10°F for Test E01, Phase I.

f. Complete Test E01 by fulfilling the requirements of Table 10 for temperature, pressure and heat transfer for 1000 cycles. The manufacturer shall define the manner in which the five phases are to be mixed for this procedure.

g. Expose transparency T04 and T06 to 50 hours of ultraviolet exposure at intervals of approximately 120 hours of cyclic testing until 600 hours of ultraviolet radiation have been accumulated.

h. Complete the five phases as required per Table 10 for two lifetimes.

i. Install transparency T05 to the crew module. Complete Tests E02 and E03 by repeating 20.6.a through 20.6.i. Complete the bird impact Test B05 per section 10.

j. Complete Test E04 on Transparency T06.

APPENDIX III

30. INTERLAYER SHEAR TEST PROCEDURE

30.1 Scope. These are procedures for determination of the bond integrity of transparent laminates. The laminates are usually made of two or more hard plastic sheets held together by an elastomeric material. These test methods are intended to provide a means of determining the strength of the bond between the plastic and the elastomeric interlayer under mechanical loading conditions. This procedure is an excerpt from ASTM:STD-F521.

30.2 Applicable Document. ASTM:D952-51: Bond Strength of Plastics and Electrical Insulating Materials.

30.3 Significance

30.3.1 Interlayer Integrity. These tests provide a means to quantitatively measure the bond integrity between the outer layers of the transparency and the interlayer, or to measure the cohesive properties of the interlayer, under various loading conditions.

30.3.2 Interlayer Quality Control. These tests provide empirical results useful for control purposes, correlation with service results, and as quality control tests for acceptance of production parts.

30.3.3 Laboratory Samples versus Full Size Parts. Test results obtained on small, laboratory size samples shown herein should be considered indicatvie of full size part capability, but are not necessarily usable for design purposes.

30.4 Definitions

30.4.1 Interlayer. Transparent material used as the bonding agent between two or more hard, transparent materials.

30.4.2 Face Plies. Transparent glass or plastic outer materials joined together with an interlayer.

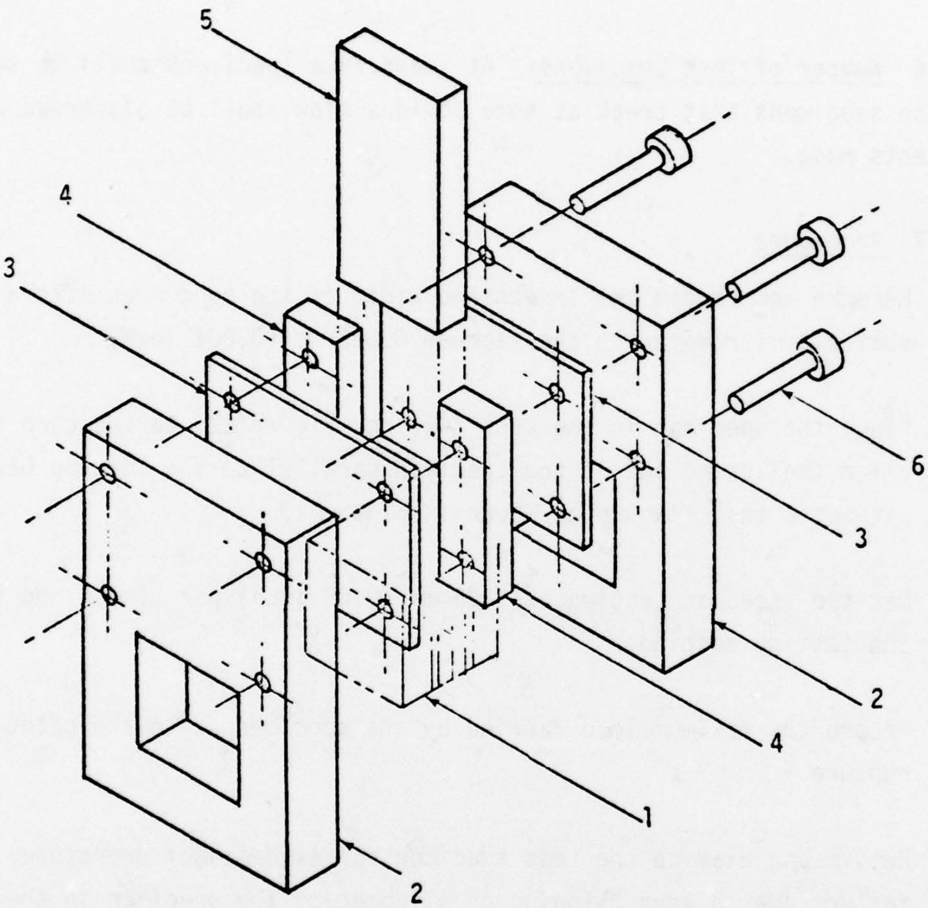
30.4.3 Delamination. A visible separation between two layers of bonded material.

30.4.4 Number of Plies. A six ply laminate has four plastic plies and two interlayer plies, where the two face plies are bonded as shown in Figure 7, Section 4.

30.4.5 Testing Machine. Any suitable machine of the constant-rate-of-cross-head movement type. The testing machine shall be equipped with the necessary drive mechanism for imparting to the cross head a uniform, controlled velocity with respect to the base. The testing machine shall also be equipped with a load-indicating mechanism capable of showing the total load applied to the test specimen. This mechanism shall be essentially free from inertial lag at the specified rate of testing and shall indicate the load with an accuracy of ±1.0 percent of the indicated value, or better.

30.4.6 Shear Strength. The shear strength is the maximum adhesive or cohesive strength between the interlayer and the outer plies when subjected to mechanical load in the direction of the plane of the interlayer. It is expressed in pounds per square inch.

30.4.7 Shear Tool. A shear test fixture of the sliding type which is so constructed that the specimen faces are firmly supported between the stationary and movable blocks to minimize peel effects. A suitable form of shear tool is shown in Figure 12 (Reference ASTM-F521).



1. Six ply shear test specimens
2. Steel housing
3. Shim (same thickness as the interlayer)
4. Steel spacer (same thickness as center ply)
5. Loading bar (hardened steel)
6. Bolts

Figure 12. Six Ply Shear Test Fixture.

30.5 Test Specimen. The test specimens are to be six ply construction as shown in Figure 7, Section 4, and shall be prepared in such a manner as to produce smooth edges to minimize premature edge chipping during testing.

30.6 Number of Test Specimens. At least five specimens shall be tested. Those specimens that break at some obvious flaw shall be discarded and retests made.

30.7 Procedure

a. Measure and record the length and width of the bond area with a suitable micrometer to the nearest 0.025 mm (0.001 inch).

b. Place the specimen in the test fixture, Figure 12, taking care to align the loaded end of the specimen parallel to the loading bar or without a test fixture as shown in Figure 13.

c. Set the speed of testing at 1.25 mm (0.05 inch) per minute and start the testing machine.

d. Record the maximum load carried by the specimen up to the point of rupture.

e. Remove and examine the test specimen for evidence of premature failure due to edge chipping or slippage of the specimen in the fixture. If premature failure has occurred, discard the sample and retest another sample.

f. Calculate the bond stress by dividing the maximum load by the bond area. For six ply tests, the area is two times the area of one of the bond line surfaces.

30.8 Report. The report shall include the following:

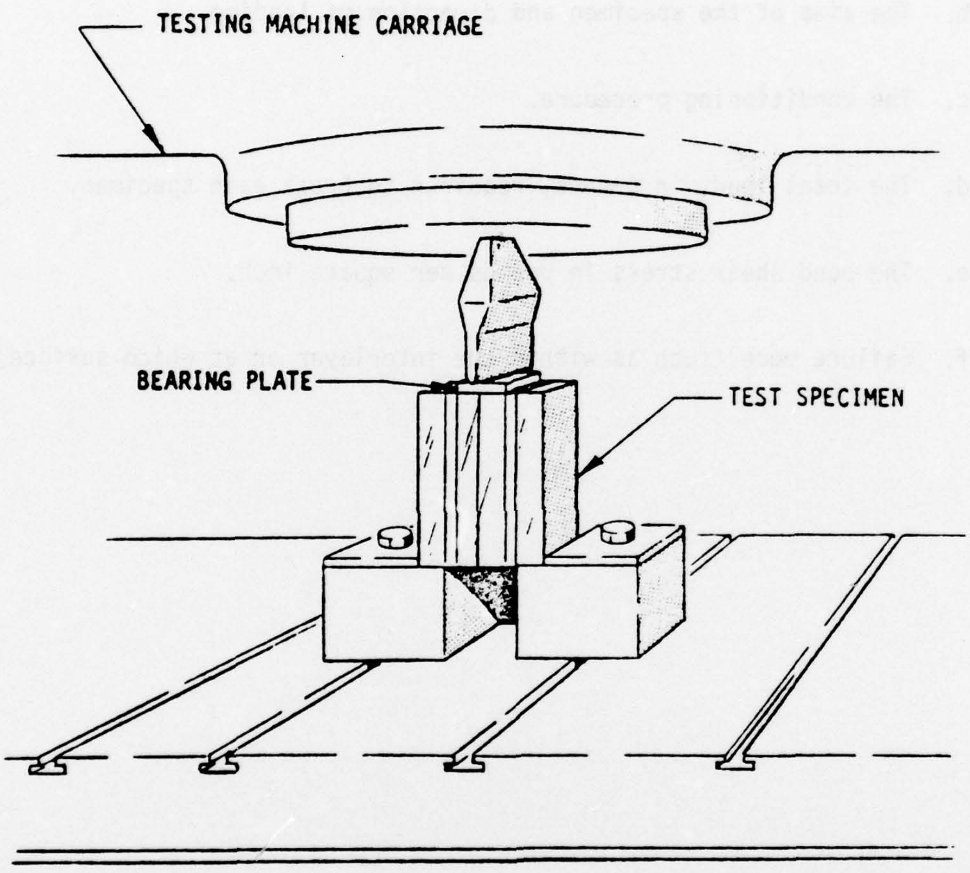


Figure 13. Alternate Shear Test Setup - Interlayer.

a. Complete identification of the material tested, including type, source, manufacturer's code number, code number, configuration principal dimensions, and previous history.

b. The size of the specimen and direction of loading.

c. The conditioning procedure.

d. The total load, in pounds, required to break each specimen.

e. The bond shear stress in pounds per square inch.

f. Failure mode (such as within the interlayer or at which surface).

APPENDIX IV

40. OPTICAL DISTORTION TEST

40.1 Test Objectives. The purpose for this series of tests is directed toward determining the optical distortion (if any) in laminated transparent windshields. Basically, this method is the measurement of slope and displacement of grid lines recorded on photographs, that were taken viewing through the transparency. The methods described in Section 50 are visual inspections utilizing a reference windshield for comparative purposes.

40.2 Facilities and Equipment

4.2.1 General. A test room of sufficient size to properly locate the required equipment must have walls, ceiling and flooring with low reflectance covering. A flat black paint or coating is preferred.

40.2.2 Grid Board. An optical grid board consisting of horizontal and vertical white lines on a dull black background. The lines shall be less than 1/16 inch wide and spaced one inch on center. The vertical and horizontal centerline of the grid board shall be identified by having every fifth line identified in sequence (5, 10, 15, etc.). The intersection of these centerlines shall coincide with the projected centerline of the camera as shown on Figure 9 for the design eye position. The grid board shall be evenly illuminated so that bright areas are not discernable to an observer's eye or on the test photographs. The grid board shall be of sufficient size to cover the entire field of view of the test camera. Table 5 lists the control dimensions for locating the windshield with respect to the camera or eye positions.

40.2.3 Holding Fixture. A holding fixture shall be provided for holding either a left or right hand windshield in the position noted in Figure 9.

The fixture shall allow the lateral positioning of the windshield with respect to the design eye position when taking photographs for the left eye and right eye positions noted. The fixture shall allow a maximum amount of grid board to be photographed.

40.2.4 Camera. A standard 4 in. x 5 in. speed graphic or equivalent camera shall be located with respect to the grid board and windshield as noted in Figure 9. The minimum dimension D (120 inches) noted will produce a photographic print as shown in Figure 14 if a theoretical 60mm (2.362 inches) focal length lens is used. The relative position of the control points are shown for the three eye positions to indicate that all photographs may be taken from one position of the camera and three positions of the windshield. Figure 15 shows the photographic print if a 90mm (3.543 inches) focal length lens is used. The dimension D of Figure 10 may be increased as long as the grid board shows around the windshield in the photograph. The camera format shall have four indices indicating the centerline of the camera as shown in Figure 14. These indices, if located on the grid board, shall not be photographed through the windshield. These indices shall always appear on any contact print or enlargement.

40.2.5 Drafting Machine. A drafting board equipped with a standard drafting machine shall be provided.

40.3 Test Specimen Cleaning. The part to be analyzed shall be cleaned in accordance with an acceptable procedure appropriate for the windshield material to remove any lint or contaminating materials which might cause localized optical distortion.

40.4 Procedure

40.4.1 Photographic. Four photographs of the grid board shall be prepared for each preproduction article as follows: (1) a control

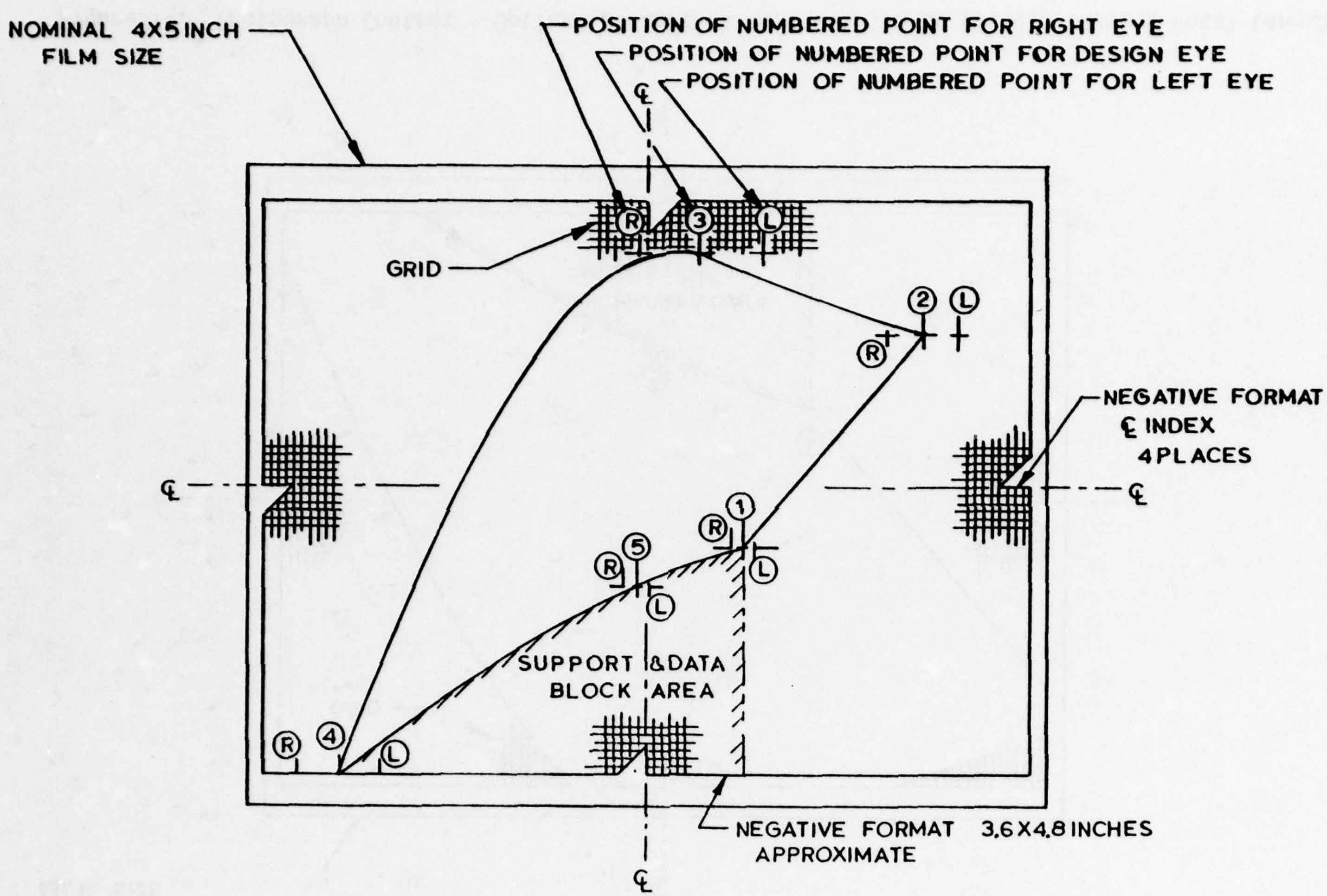


Figure 14. Photograph Content - Optical Distortion Test 60 mm (2.362 Inches) focal Length Lens.

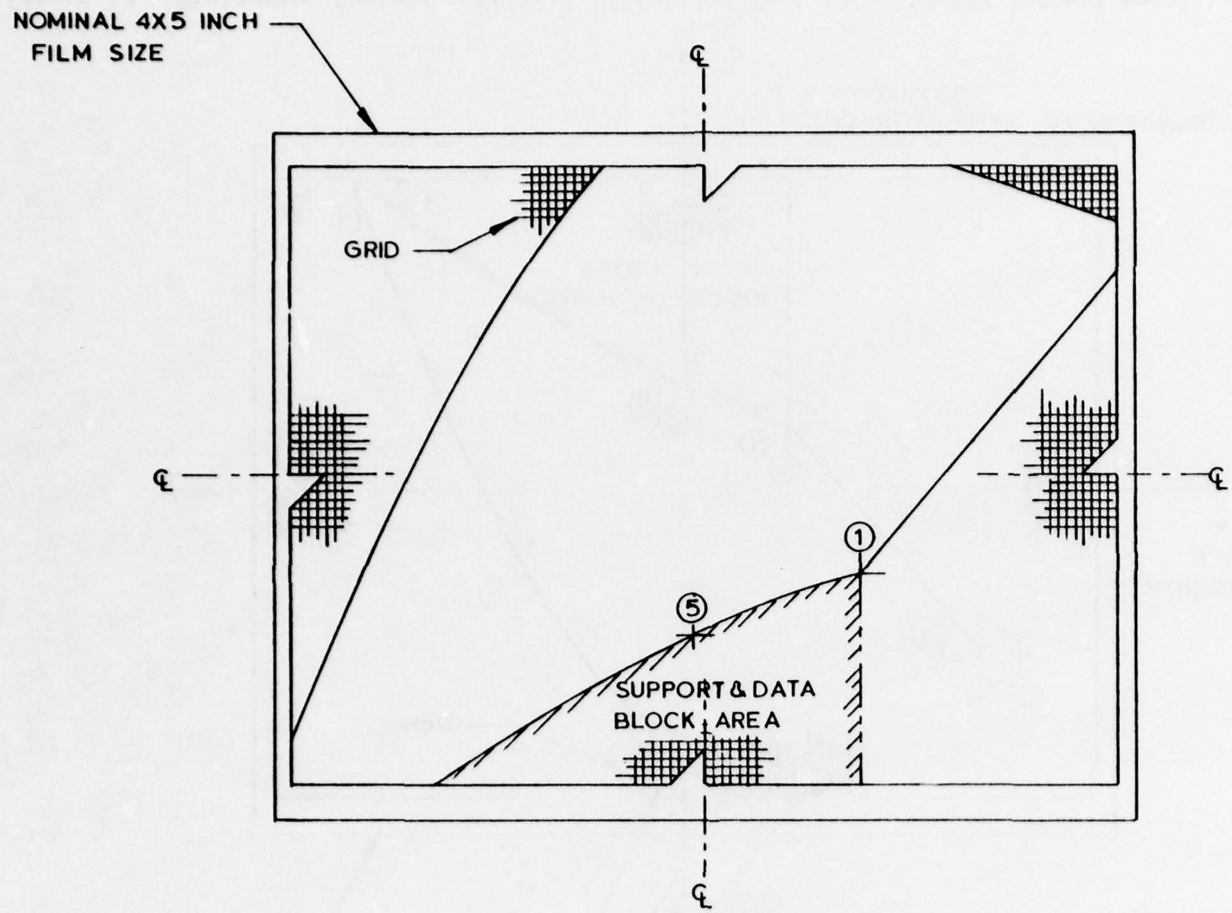


Figure 15. Photograph Content - Optical Distortion Test with 90 mm (3.5433 Inches) Focal Length Lens.

photograph with no windshield in place, (2) a photograph for the right eye position, (3) a photograph for the design eye position, (4) a photograph for the left eye position. The camera shall be focused only once for number (1) and all subsequent photographs shall be taken at this setting. Each photograph shall contain the following data in the area noted on Figure 14.:

Specimen Part Number and Change Letter
Specimen Serial Number
Supplier Identification
Date of Test
Dimension "D" (Figure 9)
Camera Negative Format Size (Figure 14)
Camera Lens Focal Length - fl

Four photographs of the grid board shall also be prepared for each production article. Upon approval by the procuring agency, the number (1) and number (3) photographs only shall be taken for subsequent production articles.

40.4.2 <u>Processing of Negatives</u>. Each group of negatives for a given windshield shall be processed together. When enlargements are prepared, the enlarger shall be set with the number (1) negative. The enlargement shall include the four indices noted in Figure 14. The three remaining negatives for the given windshield shall be enlarged using the same setting as number (1). All prints shall be glossy finish and shall be processed the same.

40.4.3 <u>Photographic Print Quality</u>. Each control and test photographic print shall meet the following requirements prior to performing the distortion analysis.

40.4.3.1 <u>Control Photograph</u>. The horizontal scale of a drafting machine

shall be aligned with the two horizontal indices of the print. Find the intersection of a horizontal and vertical line through the four indices. This is the optical center of the camera. Using the nearest horizontal and vertical grid lines, check the grid lines for parallelism with respect to the horizontal and vertical axis of the photographic print. If the lines are not parallel, re-align the horizontal scale of the drafting machine with the horizontal grid line nearest the optical center. Using this setting mark corrected horizontal and vertical indices and reference lines that pass through the optical center. Starting with the corrected orientation of the horizontal axis, check the parallelism of every tenth grid line above and below the horizontal axis. No line shall deviate from the horizontal by more than one quarter of a square in any five inch length either side of the vertical centerline. Starting with the center vertical line, the vertical grid lines shall be checked for perpendicularity to the horizontal lines. No lines, spaced every five squares maximum, shall deviate from vertical by more than one quarter square in any five-inch length above or below the central horizontal line.

40.4.3.2 Test Photographs. The three test photographic prints shall be checked for the orientation of the horizontal and vertical axes. If the camera has not been moved, the control photographic print and the three test prints should be the same. Mark each test print with the axis orientation established on the control print. In the areas of the test photographs that are outside the windshield perimeter, check the perpendicularity of grid lines in the same manner as the control print.

40.4.3.3 Enlargement Size. The actual enlargement (m) of the negatives used in pareparing the four prints shall be determined and marked on the print.

The value m is determined by dividing the length of ten squares on the photographic print by the length of ten squares on the negative. Use only the areas unobstructed by the test article for this determination.

40.4.4 Distortion Analysis. Using the four photographic prints, verify the distortion performance requirements using the following procedure: (Note: All points compared in the following steps are on the same horizontal grid line.)

Step 1. Identify points on the grid board as shown on Figure 16. The number of points selected shall be determined by the zone outlines of Figure 1. The points selected within Zone 1 shall not exceed the spacing along each centerline as noted in Figure 16 and shall not exceed the ten square spacing in all other areas.

Step 2. Calculate and record, as shown on Figure 17 (Form 1), the true azimuth and elevation angles in degrees for each point selected on the grid board using the following equations:

$$\text{Azimuth } \beta_n = \text{Arctan } \frac{Y_n}{\sqrt{D^2 + Z_n^2}}$$

$$\text{Elevation } \theta_n = \text{Arctan } \frac{Z_n}{\sqrt{Y_n^2 + D^2}}$$

Step 3. Starting with the control photograph, calculate and record as shown on Figure 17 (Form 1), the apparent azimuth and elevation angles in degrees for each of the selected points on the four photographs, for each transparency, using the following equations:

$$\text{Azimuth } \beta_{na} = \text{Arctan } \frac{S_n}{\sqrt{(mf\ell)^2 + Z_{na}^2}}$$

$$\text{Elevation } \theta_{na} = \text{Arctan } \frac{Z_{na}}{\sqrt{S_n{}^2 + (mf\ell)^2}}$$

Step 4. Calculate and record, as shown on Figure 17 (Form 2), the true azimuth and elevation angles between successive points on the same horizontal grid line using the data calculated in Step 2.

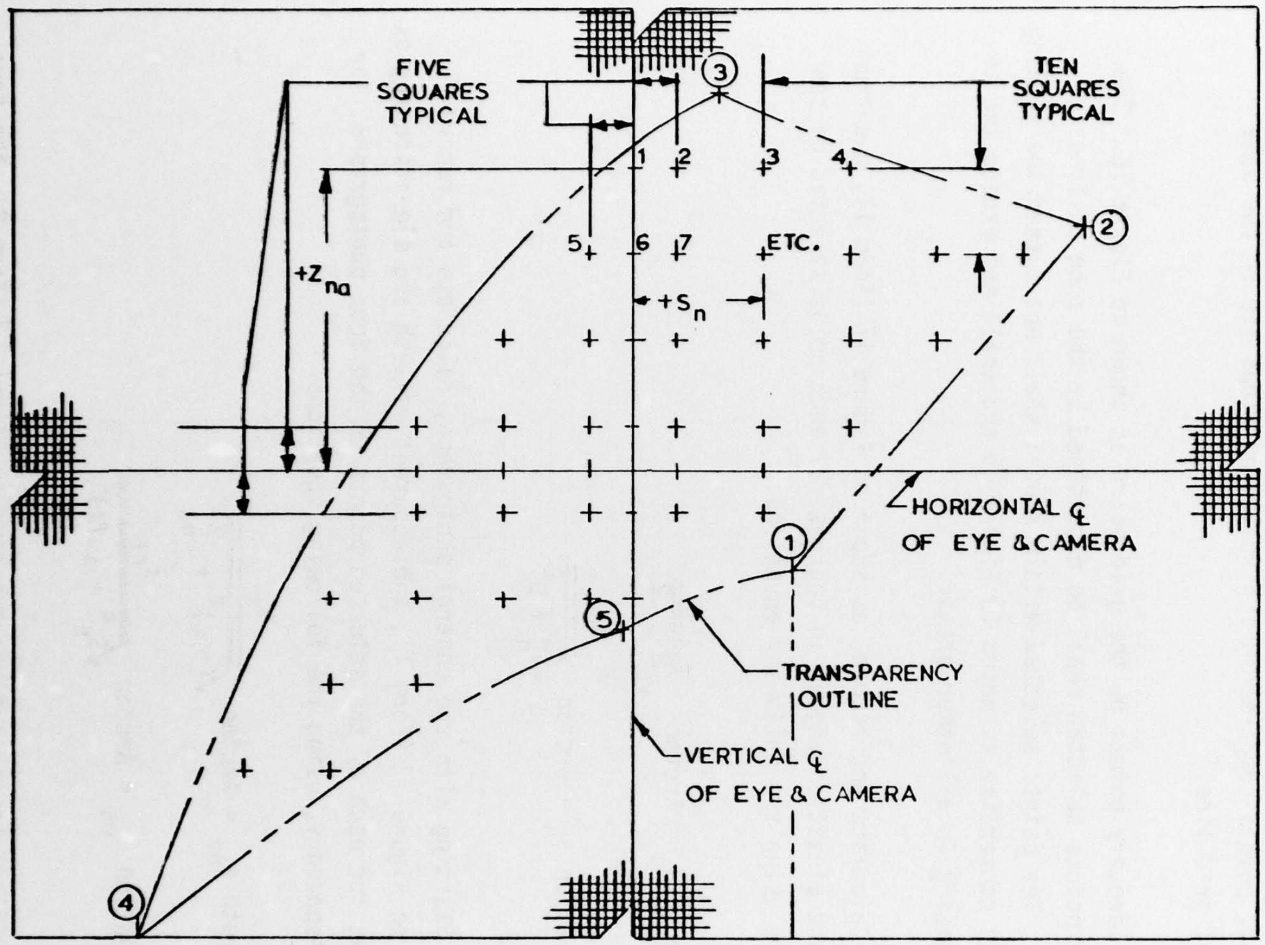


Figure 16. Distortion Points - Numbering for Analysis.

D =(FIGURE 10) PHOTOGRAPH (SECTION 40.4.1)

POINTS	TRUE COORDINATES		TRUE AZIMUTH	TRUE ELEVATION	PHOTO COORDINATES		APPARENT AZIMUTH	APPARENT ELEVATION
n	Y_n	Z_n	β_n	θ_n	S_n	Z_{na}	β_{na}	θ_{na}
1	Y_1	Z_1	$\beta 1$	$\theta 1$	$S1$	1a	$\beta 1a$	$\theta 1a$
2	Y_2	Z_2	$\beta 2$	$\theta 2$	$S2$	2a	$\beta 2a$	$\theta 2a$
3	Y_3	Z_3	$\beta 3$	$\theta 3$	S_3	3a	$\beta 3a$	$\theta 3a$
Etc.								
STEP 2					STEP 3			

a. Form 1

	GRID BOARD		PHOTOGRAPH (SECTION 40.4.1)	
POINTS COL (1)	$\Delta\beta_n$, n + 1 COL (2)	$\Delta\theta_n$, n + 1 COL (3)	$\Delta\beta_{na}$, n + 1a COL (4)	$\Delta\theta_{na}$, n + 1a COL (5)
1, 2	$\beta_1 - \beta_2$	$\theta 1 - \theta 2$	$\beta 1a - \beta 2a$	$\theta 1a - \theta 2a$
2, 3	$\beta 2 - \beta 3$	$\theta 2 - \theta 3$	$\beta 2a - \beta 3a$	$\theta 2a - \theta 3a$
Etc.				
STEP 4			STEP 5 STEP 6	

b. Form 2

Figure 17. Recording Format - Distortion Analysis.

Step 5. From the control photograph, calculate and record, as shown on Figure 17 (Form 2), the apparent azimuth, Column 4, and elevation, Column 5, angles between the Step 3 points using the data calculated in Step 3.

Step 6. The grid board and control photograph calculations performed in Steps 2 through 5 should produce the same angles for any given point or points. Any difference will indicate the accuracy of the camera and photographic print processing and shall be less than five minutes of arc in either the horizontal or vertical directions and shall be determined as follows:

Using the data recorded in Steps 4 and 5, shown in Figure 17 (Form 2), calculate the horizontal convergence/divergence errors and vertical supervergence error, in minutes of arc, and record as shown in Figure 18, Form 3:

Horizontal convergence error $\Delta\delta_c$ = [column (2) - column (4)] 60 (when column 2 > column 4).

Horizontal divergence error $\Delta\delta_d$ = [column (4) - column (2)] 60 (when column 2 < column 4).

Vertical supervergence error $\Delta\delta_s$ = [column (3) - column (5)] 60

Step 7. Repeat Step 5 for the design eye (DE). Using the data obtained in Step 5 for the control photograph (CP) calculate the horizontal and vertical magnification (+m)/minification (-m), in the design eye photograph as follows:

Let $\mu' = \beta_{1a}-\beta_{2a}$ for the DE photograph and
$\mu = \beta_{1a}-\beta_{2a}$ for the CP photograph, then

$$\pm m\ \% = \left(\frac{\tan \mu'}{\tan \mu} - 1\right) \times 100$$

TITLE: GRID BOARD VS CONTROL PHOTOGRAPH (CP)			
POINTS	HORIZONTAL CONVERGENCE ERROR $\Delta\delta_c$	HORIZONTAL DIVERGENCE ERROR $\Delta\delta_d$	VERTICAL SUPERVERGENCE ERROR $\Delta\delta_s$
1-2 2-3 etc.			

a. Form 3

	CP VS DE PHOTO HORIZONTAL MAGNIFICATION		CP VS DE PHOTO VERTICAL MAGNIFICATION		LE VS RE PHOTO BINOCULAR		
POINTS	+m	-m	+m	-m	CONVERGENCE $\Delta\delta_c$	DIVERGENCE $\Delta\delta_d$	SUPERVERGENCE $\pm\Delta\delta_s$
1-2 2-3 etc.							

b. Form 4

POINTS	AZIMUTH DEVIATION $\Delta\delta_{AZ}$	ELEVATION DEVIATION $\Delta\delta_{EL}$
1(LE)-1(RE)	$\beta_{1a}-\beta_{1a}$	$\theta_{1a}-\theta_{1a}$
2(LE)-2(RE)	$\beta_{2a}-\beta_{2a}$	$\theta_{2a}-\theta_{2a}$
etc.		

c. Form 5

Figure 18. Recording Format - Convergency/Divergence.

The magnification shall not exceed $\pm 5\%$ in Zone 1. Record the results on Form 4 of Figure 18. For the vertical m, substitute $\theta_{1a}-\theta_{2a}$, etc., in the above equations.

Step 8. Calculate the binocular convergence and divergence and supervergence between points using the data in Column (4) and Column (5) of Figure 17 (Form 2), for each of the combinations shown below and record the data as shown in Figure 18, Form 4.

LE photograph vs RE photograph

(LE col 4 > RE col 4), $\Delta\delta_c$ = [(LE col 4) - (RE col 4)] 60

(RE col 4 > LE col 4), $\Delta\delta_d$ = [(RE col 4) - (LE col 4)] 60

LE photograph vs RE photograph, col 5

(LE col 5 > RE col 5), $\pm\Delta\delta_s$ = [(LE col 5) - (RE col 5)] 60

No angle recorded shall exceed five minutes of arc for any points spaced five squares apart and no angle recorded shall exceed ten minutes of arc for any points spaced ten squares apart per Section 3.2.1.4.3.

Step 9. The azimuth and elevation deviation of a common point ray trace to the left and right eyes shall be determined from the data recorded in the Form 1 of Figure 17 for apparent azimuth and elevation of the selected points on the LE and RE photographs.

Azimuth Deviation - $\Delta\delta_{AZ} = [\beta_{1a}\,(LE) - \beta_{1a}\,(RE)]\ 60$

Elevation Deviation - $\Delta\delta_{EL} = [\theta_{1a}\,(LE) - \theta_{1a}\,(RE)]\ 60$

The data shall be recorded on Form 5 of Figure 18 and shall not exceed ten minutes of arc in azimuth or elevation for any common point of interest to the LE and RE.

Step 10. For any apparent bending, blurring, divergency or convergency of any lines between the selected points in Step 1, these shall be

identified, analyzed and reported in the same procedure used in Steps 1 through 9.

40.4.5 Grid Line Slope. The slope of a straight line between two points shall be determined for all lines horizontally connecting the points used in Section 4.0.4.4, Steps 1 through 10. A straight edge may be used to check any line with the grid lines photographed in the control photograph. An alternate and more preferable method makes use of the data recorded in Figure 17, Form 1 as follows:

$$\text{Slope} = 1{:}X$$

where

$$X = \frac{S_2-S_1}{Z_{2a}-Z_{1a}}, \text{ etc.}$$

The slope shall not exceed the requirements of Section 3.2.1.4.3.

APPENDIX V

50. SELECTION AND USE OF THE REFEREE WINDSHIELD

50.1 General

50.1.1 At dates to be agreed upon, Air Force representatives shall visit the contractor's production site. These shall be the USAF referee team and shall be designated in a letter to the contractor. During the visit the procuring agency representatives shall be presented with the collection of at least 12 left and right hand windshields which are: (1) currently in production, (2) amenable to mounting for viewing, (i.e., not in a curing stage or susceptible to reoperation), (3) have all applicable optical data inspections performed, and (4) do not exceed the specified lensing and displacement limits by more than 4 percent.

50.1.2 From this collection, procuring agency representatives and manufacturer's representatives shall select one left hand windshield and/or right hand windshield which will serve as the visual optical standard or Referee Windshield until changed by the team. All windshields fabricated subsequent to the selection data of the Referee Windshield shall be equal to or better than the Referee Windshield with respect to only the characteristic of "Visual Optical Distortion".

50.1.3 The Referee Windshield shall be designated in a joint letter signed by the members of the procuring agency/manufacturer.

50.1.4 The Referee Windshield shall be held at the manufacturer's facility until a new referee is chosen. The Referee Windshield shall be used only as an inspection standard for "Visual Optical Distortion" by the manufacturer's Inspection Department. The Referee Windshield shall be protected when not in use and shall receive no additional processing without the unanimous consent of the Referee Team.

50.1.5 When a new referee windshield is chosen, the previous Referee Windshield shall be re-examined. If re-examination indicates this Referee Windshield is acceptable for all other optical criteria, it shall be considered fit for use without prejudice from the newly selected Referee Windshield.

50.2 Procedure for Selection of Referee Windshield

50.2.1 A magnitude estimation judgment procedure will be followed for the evaluation of visual quality of the windshields selected for evaluation in paragraph 50.1.

50.2.2 The magnitude estimation procedure requires a team member to judge the relative magnitude of the visual quality of windshield with respect to the standard windshield designated by the Referee Team Leader.

50.2.3 A separate judgment will be made for distortion, multiple imaging, and rainbowing. The standard windshield is assigned to a value of 50 to represent its perceived magnitude for the visual problem being evaluated. Each windshield will be compared, one at a time, with the standard and a numerical value assigned which represents the perceived relationship between the standard and the examined windshield regarding the optical aberration being evaluated.

50.2.3.1 If the team member perceived half as much distortion, multiple imaging or rainbowing in a windshield when compared to the standard, a value to 25 would be assigned.

50.2.3.2 If the team member perceived twice as much distortion, multiple imaging or rainbowing in a windshield when compared to the standard, a value to 100 would be assigned.

50.2.3.3 Each team member makes evaluations independently and without knowledge of the judgments of the other members.

50.2.3.4 Numerical values are recorded. The Referee Windshield shall be chosen from those windshields examined by subsequent agreement among the Referee Team representatives in accordance with paragraph 50.1.2.

50.3 Test Conditions for the Selection of the Referee Windshield. The following viewing arrangement will be used for magnitude estimates of windshield visual quality.

50.3.1 Distortion. Test Pattern - One inch square grid board with white lines on a black background and large enough to cover the field of view through a windshield as seen from the design eye position (section 40.2.2).

Lighting - A minimum of 10 foot lamberts is required on the grid board, with no large illumination variations across the areas of the grid board used for visual comparisons.

Windshield - Place in the installed orientation, with the design eye position 200 inches from the test pattern. The standard and comparison production windshields should be located side-by-side.

50.3.2 Multiple Imaging. Test Pattern - Six by six inch square grid board, with 1/8 inch wide white lines on a black background, and at least 11 feet high by 16 feet wide.

Lighting - Use a light box to uniformly back illuminate the test pattern (luminance: minimum 300 foot lamberts without the test pattern in position).

Windshield - Place in the installed orientation, with the design eye position 200 inches from the test pattern. The standard and comparison windshields should be located side by side.

50.3.3 Rainbowing. Test Pattern - Eighty percent polarized screen (see paragraph 4.2.4.8).

Lighting - Use a light box to back illuminate the polarized screen uniformly (luminance: minimum 300 foot lamberts without the screen in position).

Windshield - Place in the installed orientation, less than 39 inches from the test pattern. The standard and comparison windshields should be located side by side. Mask the forward end of the windshield to reduce reflections.

50.3.4 Viewing Procedures. All judgments are to be made from the design eye position. Each windshield is to be covered with a mask to occlude those areas for which the manufacturer is not responsible for meeting optical specifications. The standard windshield should be viewed first, followed by the windshield under inspection. The judge should be allowed to alternately view the standard windshield and the inspected windshield as desired.

50.4 Procedure for Visual Optical Distortion Evaluation of Production Windshields

50.4.1 Each production windshield shall be visually evaluated by the Quality Control Section.

50.4.2 Such Evaluation shall be made with the Referee Windshield present for visual comparison.

50.4.3 The Referee Windshield represents the desired minimum level of "Visual Optical Distortion". "Visual Optical Distortion" is the fidelity with which a target object can be seen through an optical medium.

50.4.4 When the production windshield is better than the Referee Windshield for "Visual Optical Distortion", the production windshield

is acceptable for this characteristic only. "Visual Optical Distortion" refers to perceived irregularities in a target object which results when the target object is observed through an optical medium. "Visual Optical Distortion" does not include structural and/or material defects of the optical medium per se, but may be the visual consequences of such defects.

50.5 Visual Optical Distortion Criteria

50.5.1 When the production windshield is not better than the Referee Windshield for "Visual Optical Distortion", the production windshield shall be held for evaluation by the contractor's quality control chief and two other procuring agency inspectors by the "Magnitude Estimation Procedure" below.

50.5.2 All transactions and decisions shall be properly documented by the manufacturer's Quality Control Section.

50.5.3 All windshields which fail to meet the requirements for "Lens Factor and/or Displacement Grade" shall be held for the "Magnitude Estimation Procedure".

50.6 Magnitude Estimation Procedure for Contractor Review of Marginal Windshields. A magnitude estimation judgment method is to be used for evaluation of windshield visual quality. The standard viewing arrangement shall be that described in paragraph 4.2.4.5.4.

50.6.1 The Referee Windshield is assigned a value of 50 to represent its perceived magnitude of "Visual Optical Distortion". Windshields being evaluated by this procedure shall be compared, one at a time, with the Referee Windshield and a numerical value assigned which represents the perceived relationship between the Referee windshield and the production windshield regarding the "Visual Optical Distortion".

50.6.2 If the judge perceived half as much distortion in the production windshield when compared to the Referee Windshield, a value of 25 would be assigned.

50.6.3 If the judge perceived twice as much distortion in the production windshield when compared to the Referee Windshield, a value of 100 would be assigned.

50.6.4 Each judge makes evaluations independently and without knowledge of the judgments of the other judges.

50.6.5 Numerical values are recorded. If the resultant average numerical value is equal to or less than the Referee Windshield value (50), the production windshield is a candidate for acceptance and is held for procuring agency review. Otherwise, the production windshield is rejected.

50.6.6 All values and decisions shall be properly recorded on the Quality Assurance Check sheets.

50.6.7 All judgments are to be made from the design eye position. Each windshield is to be covered with a mask to occlude those areas for which the manufacturer is not responsible for meeting optical requirements. The Referee Windshield should be viewed first, followed by the production windshield. The judge should be allowed alternate viewing through the Referee Windshield and the production windshield as desired.

50.7 Procuring Agency Review of Marginal Windshields. The manufacturer will request a procuring agency review of marginal windshields when the quantity of such candidates is not less than ten (10). The procuring agency judge may use the characteristics of visual optical distortion, multiple imaging, and birefringence to compare the marginal windshields

against the Referee Windshield. Procuring agency review decisions shall be entered on Material Review Record (MRR) forms for each part. Acceptance shall be indicated by the signature of the procuring agency judge and the manufacturer's responsible Material Review Board authority.

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